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142798

Site Selection Study

SUPPLEMENT

US Army Corps
of Engineers
Chicago District

Waukegan Harbor, Illinois

Confined Dredged Disposal Facility

June 1986

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION V

DATE: JUN 23 1986

SUBJECT: Request to Review Supplement to Site Selection Study For Waukegan Harbor CDF

FROM: William Franz, Chief Bill Franz
Environmental Review Branch, 5ME

TO: Addressees

The Chicago District, COE, has requested that we review the attached supplement to the site selection study performed in May, 1984 for disposal of sediments from Waukegan Harbor. The site selection study included consideration of three alternative land sites. The supplement includes consideration of four alternative in-lake sites.

The cover letter for the supplement indicates that a workshop is planned to be held for interagency discussion after submittal of initial comments. Kay Brennan of my staff will coordinate the submittal of our comments on the potential in-lake sites and our preference for a date for the workshop.

Please have the appropriate member or members of your staff review this supplement. The staff member(s) reviewing the document should contact Kay (6-6873) by June 30, 1986, to express their preference for the workshop date. Your comments should be submitted to Kay by July 4, 1986. Please call her if you have any questions.

Attachment

Addressees:

Vacys Saulys, 5GL
Kenneth Fenner, 5WCC
Karl Bremer, 5SPT
Richard Bartelt, 5HR

RECEIVED
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REMEDIAL
RESPONSE BRANCH

EPA FORM 1320-6 (REV. 3-76)

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, CORPS OF ENGINEERS
219 SOUTH DEARBORN STREET
CHICAGO, ILLINOIS 60604-1797

5 JUN 1986

RECEIVED
JUN 9 1986
ENVIRONMENTAL REVIEW BRANCH
PLANNING & MANAGEMENT DIV.

REPLY TO
ATTENTION OF
Plan Formulation

Mr. William Franz, Chief
Environmental Review Branch
U.S. Environmental Protection Agency
230 South Dearborn Street
Chicago, Illinois 60604

Dear Mr. Franz:

Enclosed is a supplement to the site selection report on a confined dredge material disposal facility at Waukegan, Illinois, completed in April 1984. The original report, which was previously furnished to your office for review and comment, identified three upland sites as being potentially feasible. However, the present uncertainty as to the availability of these sites and the lack of a local sponsor has led to consideration of potential lake sites. The Waukegan Port District has indicated an interest in sponsoring a lake site immediately south of the existing recreational boat harbor.

The supplement evaluates the costs and other impacts of four alternative lake sites, all located in the same general area. One site was identified as the most feasible, based primarily on costs, since the other impacts were very similar. We would appreciate receiving any comments which you may have on the plans evaluated in this supplement by June 30.

Once comments on the lake sites/plans are received, a workshop will be scheduled among all interested agencies to discuss their concerns on both the land and lake sites. Please include with your comments your preferences for a workshop date during the week of July 14-18. You will be notified of the workshop arrangements by July 3. If your staff has any questions, please contact Mr. Mike Fisher of our Plan Formulation Branch. His telephone number is (312) 353-6490.

Sincerely,

Frank R. Finch

Frank R. Finch, P.E.
LTC, Corps of Engineers
District Engineer

Enclosure

WAUKEGAN HARBOR, ILLINOIS
CONFINED DREDGED MATERIAL
DISPOSAL FACILITY
SITE SELECTION STUDY
Supplement

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Site Selection Study - Supplement

1. PURPOSE OF REPORT

This report, which summarizes the results of engineering, cost and environmental analyses of four alternative confined disposal facilities (CDF's) located in Lake Michigan near Waukegan Harbor, is a supplement to the site selection study for Waukegan Harbor completed in April 1984. The original study identified three upland sites as most likely to be implementable. However, difficulties have arisen concerning each of the considered sites.

a. Original Sites' Status:

(1) Site 1 - Airport Site: The FAA made a determination that the required clear zone for the airport would be less than originally anticipated. Therefore the Waukegan Port District decided only to acquire the required acreage, which is not sufficient to contain all the expected dredged material.

(2) Site 4 - Old Farm: No agency has expressed an interest in acquiring the site and becoming the local sponsor.

(3) Site 16 - OMC Site: The Outboard Marine Corporation (OMC) has not indicated a willingness to sell the property. In addition, the U.S. EPA has indicated that it will, in all probability, use the site for disposal operations associated with the eventual disposal of the dredged material with PCB concentrations too great for confined disposal.

b. Additional Sites:

Because of the above general problems, the Chicago District of the COE began a reconsideration of potential CDF sites. The Waukegan Port District indicated an interest in a lake site in the near-shore area immediately south of their recreational boat harbor. After filling and capping, the top surface of such a site could be used for parking or some other marina-related activity. For this supplement, four alternative near-shore lake CDF sites have been evaluated.

2. SITE SELECTION STUDY - SUMMARY

The original site selection study was completed in April 1984. The report was completed as a basis for recommending a plan for disposing of dredged material determined to be unsuitable for open lake disposal in a confined facility.

a. Problem:

(1) Waukegan Harbor is a commercial harbor primarily serving the Gold Bond Building Products and Huron Cement Companies, both divisions of National Gypsum Company. Regular routine maintenance dredging is required to maintain adequate project depths. Through 1969, dredging was accomplished primarily with a Government-owned hopper dredge. The materials were placed in the hopper

dredge's bins or scows and bottom dumped in the established deepwater disposal area in Lake Michigan located about 2 1/2 miles east of the north breakwater light.

(2) Bottom Sediment Analysis. Prior to 1976, routine analysis of bottom sediments from Waukegan Harbor was performed by the Corps of Engineers and the USEPA/Federal Water Pollution Control Administration in relation to maintenance dredging. Sediments were commonly analyzed for organic nutrients and heavy metals. The sediments of the inner harbor (project depth -18 ft LWD) were considered polluted and not acceptable for open-water disposal. Those sediments from the outer harbor (project depth -22 ft LWD) were considered only slightly polluted. In 1976, the USEPA first discovered the presence of polychlorinated biphenyls (PCB's) in Waukegan Harbor. Since that time, the USEPA and Corps of Engineers (COE) have done extensive sampling of the harbor area and have determined that the material within the Federal channel contains less than 50 ppm PCBs. Even if the PCB material did not exist in the harbor there are other chemical constituents within the harbor material which warrant it being classified as unsuitable for open lake disposal.

(3) Character of Dredged Materials. The bottom sediments of the Waukegan Harbor have been sampled and analyzed by the USEPA (1973, 1976, 1977) and the Corps of Engineers (1981, 1982). Sediments were classified using the USEPA "Guidelines for Pollutional Classification of Bottom Sediments from Great Lakes Harbors" (1977). Most of the sediments within Waukegan Harbor west of the South Pier light are polluted and require confined disposal. However, sandy sediments along the eastern portion of the North Pier are unpolluted and can be disposed in the lake or used for beach nourishment. Survey results have shown a wide spectrum of pollutional levels, with polychlorinated biphenyls (PCBs) being the contaminant of major concern. Results of the analysis of site water indicate little evidence of pollution. Most of the contaminants appear to be contained in the sediments. A summary of the physical and chemical characteristics of the bottom sediments is contained in Appendix B of the April 1984 site selection study.

(4) Method of Dredging and Disposal since 1969. Since the discovery of PCB contamination at Waukegan, the only maintenance dredging permitted was to the east of the south pier light prior to 1984. This work was performed in 1974, 1976, 1977 and again in 1982. No dredging work west of the south pier light, in the navigation channel and inner basin, had been proposed by the Chicago District pending recommendations from USEPA up to April 1984. Limited dredging along the north pier was carried out in 1985.

(5) Maintenance Requirements. The estimated dredging backlog, based upon 1982 examination soundings, is approximately 105,000 cubic yards of material in those areas where deep draft navigation occurs. This volume includes 45,000 cubic yards of sandy sediment in the outer channel which will not require confined disposal.

(6) PCB Concentrations. The concentrations of PCB's in the bottom sediments of Waukegan Harbor vary with location and depth. A USEPA report divided the harbor into areas of specific PCB concentrations. Plate 3 is reproduced from this report. All areas of the Federal channel are identified as

having PCB concentrations less than 50 ppm. Grab and core samples of the sandy-clay and silty sediments of the inner harbor (Area 4) contained PCB levels well below 50 ppm. Analysis of the silty-sand and sand from Area 6 showed PCB concentrations less than 1.0 ppm throughout.

(7) Area of Dredging. The Corps of Engineers is limited to dredging the authorized Federal channel, as shown on Plate 2, at Waukegan. According to a report submitted to the USEPA by Mason and Hanger - Silas Mason Co. in January 1981, the entire top soft muck sediment layer is contaminated with PCB down to the underlying sand at almost all locations where any PCB contamination occurs. Within the general area of the authorized COE project, contaminated sediment is located below authorized project depths and immediately outside of project boundaries. If COE dredging is restricted only to authorized project limits, it is likely that portions of the remaining, exposed sediment will drift into the authorized project area resulting in additional handling problems and costs for many cycles of future dredging. In order to avoid this, the Corps would need to dredge, deeper than the authorized depths shown on Plate 2 and also would need to dredge outside the limits of the channel to remove sediments next to piers and bulkheads. It seems probable therefore that, if the COE does any dredging in Waukegan Harbor, it will, at the least, have to dredge all soft muck sediments from the Federal Channel. This will exceed the present authorization for dredging by COE. The USEPA and Illinois EPA have identified only those areas contaminated with more than 50 ppm PCB for clean-up. The net result is that the area between the Corps project and EPA project would remain untouched and contaminated unless some effort were initiated to clean it up. If this area were not dredged at the same time or prior to the time the Federal Channel was dredged, PCB would migrate to the Federal Channel and dredge material from future maintenance dredging would very likely contain more than 10 ppm PCB ~~and~~ require confined disposal. It would be much more economical to clean up the entire harbor at once rather than deal with the PCB contamination in maintenance dredging year-after-year. In addition, the US Environmental Protection Agency has recommended that, following dredging operations, the level of PCB at the exposed surface of sediment not exceed the level which was at the surface prior to dredging. In the judgment of the Chicago District, it is likely that the additional authorization and funding for this work will be received.

b. Authorization:

In the April 1984 Site Selection Study, the authorization under which implementation was being considered was Section 123 of the 1970 River and Harbor Acts (PL 91-611). This act authorizes the construction of confined dredge disposal facilities to hold maintenance dredgings which are produced over a period not to exceed 10 years, and which are classified as unsuitable for open lake disposal by the Administrator, U.S. Environmental Protection Agency (USEPA). Under this program, the cost of construction and maintenance is primarily borne by the Federal Government with local interests required to provide rights-of-way and certain other assurances. The design capacity is based on an estimate of the total amount of polluted material which will be dredged in a particular harbor over a period of ten years.

c. Sites Investigated:

With the assistance of other agencies, 15 alternative sites were selected to be evaluated as possible disposal locations for material dredged from the navigation channel at Waukegan Harbor. Of the original 15 sites, nine were selected for further study. Of those nine selected for further study, three were selected for detailed study and evaluation for possible recommendation as the selected site. The three sites (sites 1, 4, and 16) are described in paragraph 1a.

d. Study Conclusions:

No final recommendation was made as to which of the sites would be used for the dredgings from Waukegan Harbor. Only the facts and costs were presented in the site selection study. A final determination was to be based on a consideration of construction and operation costs, environmental impacts, and the desires and concerns of a local sponsor, local and Federal agencies and the general public.

e. Current Status:

The three sites selected for final evaluation are still viable sites. However, because of the problems associated with them, especially the lack of any qualified agency to exhibit any significant degree of interest in sponsoring one of the sites, their appeal has diminished. Therefore, the Chicago District has decided to reconsider other sites which might prove to be more implementable.

3. LAKE SITES

a. Waukegan Harbor Area:

The Waukegan Regional Port District has requested that consideration be given to the construction of a confined disposal facility in the near-shore area just south of the existing recreational boat harbor. Advantages include the proximity to the dredging site and the use the Port District could make of the land area created after filling and capping of the structure, in conjunction with planned expansion of their recreational harbor facilities. The Port District has indicated that they may be the local sponsor for the project.

b. Dredging Volumes:

The contaminated sediment within the Waukegan Harbor area can be categorized in a number of ways, including degree of PCB contamination and location within the authorized Federal navigation project. This is discussed in paragraph 7c of the Site Selection Study and paragraph 2a(7) of this supplement, and shown on plate 3. In the judgment of the Chicago District, the public interest will best be served, and the economic and environmental benefits of the project will maximized, if all the contaminated sediment with PCB concentrations ranging from 10 PPM to 50 PPM is dredged at once and confined within the proposed structure. This would require an estimated capacity of 188,000 cubic yards. In addition, if the sediment in the north harbor with a higher PCB concentration level is not removed concurrently with the initially dredged material, quantities of this material are likely to be washed downstream into the project area and diluted to concentration levels suitable for confinement. Based upon an estimate of the volume of the highly contaminated north harbor material, an additional capacity of 32,000 cubic yards will be designed into the proposed structure, for a nominal total capacity of 220,000 cubic yards. All considered structures will be designed to contain this volume.

c. Authority:

Since the maintenance dredging of the authorized Federal project is a Federal responsibility, and since it is Federal regulations that mandate that the dredged material be confined, the Corps of Engineers (COE) has determined that CDF's can be constructed under regular operations and maintenance authorities in cases like the one at Waukegan Harbor. In this case, a local sponsor is not absolutely required as under Section 123, 1970 River and Harbor Act (PL 91-611) authorization. The COE does make it a policy that a local sponsor participate in the implementation of confined disposal projects unless it can be shown that it is in the best interests of the nation to proceed without one.

4. CDF DIKE DESIGN

The fundamental purpose of the proposed dredging/confining operation at Waukegan Harbor is to clean-up a serious environmentally hazardous water quality problem and to reestablish normal use of a Federal commercial harbor, which has been badly hindered for many years by the water quality problem. The clean-up must be accomplished without increasing the environmental hazard to any other part of the environment. The primary source of the water quality problem is the high concentration of polychlorinated biphenyls (PCB's), which varies over a wide range, present in the soft bottom sediments overlaying the bottom of Waukegan Harbor. If an acceptable, feasible upland disposal site is not provided, the dredged materials must be disposed of in a lake site. From a water quality point of view, a lake site can be perfectly acceptable as long as the breakwater/dike walls can withstand the wave forces they are subjected to and as long as they prevent contaminant substances, solid or soluble, from passing through from inside to the open lake water.

a. Lake Michigan Water Quality:

The quality of Lake Michigan water is, in general, quite high. Illinois State standards for discharges of contaminant substances to the lake are very stringent.

b. PCB and Other Contaminant Transmission:

Engineering analyses performed by the Dredged Materials Research Program (DMRP) on the PCB-sediment matrix in laboratory and field investigations have found PCB's to be strongly bound to the fine-grained sediment particles. Other contaminants of greatest concern (lead, mercury, etc.) also have strong physical-chemical bonds to the silt and clay particles. Other studies indicate that the release of PCB's from sediments to the soluble portion of the water column was generally not significant, and that the presence of PCB's in the water column was dependent on the presence of suspended solids. Standard elutriate tests conducted with Waukegan Harbor sediments demonstrated little or no release of contaminants into solution. These results are in agreement with the findings of the Corps' Dredged Material Research Program which conducted exhaustive testing of dredged material around the country. Most heavy metals were found to be tightly bound to the silty-clay particles of urban sediments. Recently, leaching tests using PCB contaminated sediments from Ashtabula River, Ohio were conducted. Columns filled with sediments were leached with artificial acid rain for a period of three months. No detectable PCB's were found in the column leachate. If a confined disposal site is to be effective from an environmental protection standpoint, it must be efficient in retaining a high percentage of the fine sediments, for it is the clays and silts which carry the contaminants. Studies of dredged material disposal areas supported these findings. The removal of PCB's closely matched the solids removal efficiencies. Filtering tests conducted with PCB contaminated sediments from the Chicago District (Indiana Harbor and the Chicago River) have supported these relationships.

c. Dike Design:

A CDF is little more than a large settling basin combined with a high restriction filter to pass water from dredgings back to the lake. The stone and sand dike which will form the CDF must serve two purposes; (1) to be a physical barrier confining those sediments which have settled, and (2) to treat all water returning to the lake by filtration. The containment structure would consist of a stonefilled dike with a prepared limestone core (see plate 4). A synthetic filter fabric and a sand filter would be placed on the disposal side to filter out the suspended solids so that the filtrate passing through the dike meets Lake Michigan's water quality standards. The sand for the filter will be dredged from within the CDF and placed on the inside slope of the dike. This layer of fine-grained sand functions like any other filter used for drinking water or wastewater treatment. Very fine material moving with the water flowing through the pores of the sand/limestone filter of the dike will eventually clog all the minute pores in the dike, substantially reducing future flow through the dike. Dike filters have been used at confined disposal facilities for dredged materials around the Great Lakes, in Chesapeake Bay, and in Japan. The only difference between the Waukegan Harbor CDF and others is the gradation of granular filter material and source of sand.

d. Dike Function:

The concentration of suspended solids in the filtrate is determined by the settling efficiency of the CDF and the filtering ability of the sand filter within the stone-filled dike. Settling tests performed with Indiana Harbor sediments show that over 99.5 percent of solids settle out within five hours. These tests were done with a suspension of sediment and water similar to that produced by a hydraulic dredge. Mechanically dredged sediments would not be slurried, and would therefore settle out even more rapidly. The use of fine-grained sand filters as a treatment for suspended solids is a widely used technology in drinking and wastewater treatment. Engineering analysis of fine-grained Lake Michigan sands indicate that over 99.999% of the suspended solids would be filtered in the first foot of filter media. The sand filter will be several feet thick. The width will be determined by constructibility criteria. The sand filter will effectively remove all suspended solids (>99.999999%). The result is that the return water from the CDF will have no suspended solids and that all sediment-bound contaminants will be confined. Engineering analysis indicates that the maximum concentrations of nutrients, metals and PCB's in the CDF filtrate will be slightly greater than the concentrations of ambient lake water. The concentrations of metals and nutrient organics will all be below the State of Illinois Lake Michigan standards. Almost all parameters will be present at levels below the detection limits of standard analytical methods. This analysis indicates that the rate of discharge from the proposed CDF will be very small compared to typical point sources, and will decrease as the facility becomes filled. The maximum rate of discharge is less than 1 cfs. The quality of water within the facility will have the greatest level of dissolved constituents at the conclusion of a dredged/disposal operation, and that this level should decrease to a level similar to the ambient lake in a short time afterwards. The quality of the water discharged from the proposed CDF will approach that of the ambient lake due to mixing and dilution within the CDF pond and dike core. In contrast, polluted sediments at the bottom of a harbor or river are directly exposed to the water column, and may be resuspended by currents or by navigation traffic. The containment of solids is the key to the disposal of dredged materials.

5. ALTERNATIVE SITES CONSIDERED

a. Plan Formulation:

(1) Four alternative CDF plans were evaluated. All would be located in the nearshore zone of Lake Michigan just south of the existing recreational boat harbor as shown on plates 5 through 8. Each would be sized to hold about 218,000 cubic yards of dredged material with space for a 2-foot thick clay cap. In several of the plans, some clean sand would be excavated from the interior of the CDF after dike construction to provide adequate volume for the dredged material. The clean excavated material would be deposited in the lake water in the near-shore zone just downdrift of the structure, as this material would provide good beach nourishment. The breakwater/dike would consist of a stone-filled dike with a prepared limestone core, as shown on plate 4. A synthetic filter fabric and a sand filter would be placed on the disposal side to filter-out the suspended solids which might otherwise cause the filtrate passing through the dike to violate Lake Michigan's water quality standards. The sand for the filter will be dredged from within the CDF and placed on the inside slope of the dike. Three of the four considered plans were located so as to not interfere with the outlet of the Waukegan River which enters Lake Michigan just south of the boat harbor. The other plan would be constructed across the mouth of the Waukegan River, but the river flow would be carried through the structure in large culverts sized to carry the 100-year frequency storm flow.

(2) The CDF would be filled to capacity in one dredging operation carried out over a short time frame soon after CDF construction. The dredged material would then have to sit and partially dry for a year or so before capping. During this time, the surface of the dredged material would be covered by a blanket of sand about one-foot thick. The purpose of the sand blanket would be to protect the surface of the not-dried dredged material from storm wave overwash and to keep the material from splashing back into the open lake water. Any water entering the CDF before it was capped, either by rain or wave overwash, would set up a hydrostatic head between the surface of the CDF pond water and the open lake water. This would be relieved as CDF water filtered through the walls of the dike. Once the dredged material had partially dried, the structure would be capped with a two-foot thickness of clay. This would be covered over with gravel and then paved with asphalt.

b. Coastal Engineering Design:

The coastal engineering analysis was performed to determine a stable breakwater/dike configuration and adequate structure heights to limit wave overwash to prevent backflow of the dredged material to the lake before the structure is capped. Since the structure will only be left uncapped for one storm season, storm criteria used in the crest height elevation analysis were less severe than those used in the stability analysis. For the crest height analysis, a five-year recurrence frequency lake level elevation was used and approximately a four-year recurrence frequency summer storm was used. In selecting the storm direction to be used in the analysis, consideration was given to the most probable direction of the most severe storm and the direction of the widest projected breakwater face. For analysis of the required armor stone size, a design storm with a 200-year recurrence frequency condition was selected (20-year recurrence water level and 10-year recurrence wave height). Details of the coastal design analysis are given in Attachment 1.

c. Geotechnical Analysis:

A reconnaissance level geotechnical analysis was made based on available data. The proposed CDF at the mouth of the Waukegan River would be underlain by from 5 to 13 feet of fine sand. Underlaying these sands could be from 15 feet to 5 feet of Lake Michigan Formation loose silts and very soft to soft lacustrine clays, subject to extreme settlement or subsidence. This material would squeeze out from under a dike with a thin underlying sand blanket. Under the Lake Michigan sediments is a moderate hard to hard clay till that would be a very good dike foundation. The sand would allow seepage and the clay/silt permit settlement. This material may also be silty sands or gravel with no intervening soft or loose materials. Additional subsurface information is given in attachment 2.

d. Plan Descriptions:

(1) Plan 9A-1. This plan, as shown on plate 5, would be constructed in the near shore water of Lake Michigan immediately south of and adjacent to the existing recreational boat harbor and immediately north of the mouth of the Waukegan River. The CDF would cover an area of 15.5 acres. The breakwater/dikes would be constructed to an elevation of +9.0 feet LWD in maximum water depths of -9.0 feet LWD. A typical cross-section is shown on plate 5. A volume of 59,000 cubic yards of clean sand would be excavated from the interior of the structure after dike construction, some of which would be used for the filter sand in the dike wall. The remainder would be deposited downdrift (south) of the structure to serve as beach nourishment. Dredged material would be placed in the CDF to a height of +4.0-foot LWD. The CDF would be filled in one season, and covered with a blanket of sand. After about one year for partial solidification, the CDF would be capped with a 2-foot thick clay cap, covered with a six-inch gravel blanket and paved.

(2) Plan 9A-2. This plan, as shown on plate 6, would be located in the same area as plan 9A-1. However, it would be constructed in slightly shallower water and be built across the mouth of the Waukegan River. The river

flow would be carried through the CDF in culverts. The site would cover an area of 14.9 acres. The breakwater/dikes would be constructed to an elevation of -9.0-foot LWD in water of maximum depth -3.0-foot LWD. After dike construction, 62,000 cubic yards of clean sand would be excavated from the structure, as in plan 9A-1. Dredged material would be placed to a height of +7.0-foot LWD. The culverts to carry the Waukegan River flow through the CDF would be sized to carry the 100-year flow. This would require five 8-foot diameter corrugated metal culverts lain on the floor of the CDF after excavation to its final bottom level. The upper end of the 5-culvert system would be laid at approximately the elevation of the current channel invert, anchored in a stone dike built across the river mouth. Low earthen dikes would line the channel banks for a short distance upstream of the junction to retain flood flows within the channel. The culvert system would be about 800 feet long. Filling, capping and paving of the structure would be very similar to that described for plan 9A-1.

(3) Plan 9B-1. This plan, as shown on plate 7, would be constructed just south of the mouth of the Waukegan River. The site would cover an area of 13.6 acres. The breakwater/dikes would be constructed to a crest elevation of +10.0-foot LWD in maximum water depths of -10.0-foot LWD. After dike construction, 11,000 cubic yards of clean sand would be excavated from the structure interior for filter sand and to provide the required capacity. Dredged material would be deposited to elevation +7.0-foot LWD. Filling, capping and paving would be done as for plan 9A-1.

(4) Plan 9B-2. This plan, as shown on plate 7, would be located in approximately the same area as plan 9B-1. The structure would cover an area of 10.8 acres. The breakwater/dikes would be constructed to a crest elevation of +10.0-foot LWD in water of maximum depth - 6.0-foot LWD. After dike construction, 77,000 cubic yards of clean sand would be excavated out of the structure to provide needed capacity. Dredged material would be placed to an elevation of +6.0-foot LWD. Dredging, solidification, capping and paving would be the same as for plan 9A-1.

e. Cost Comparisons:

Cost estimates for the considered plans are given in attachment 3, and summarized in table 1. Costs are based on the April 1986 price level.

Table 1. Cost comparison for Waukegan Harbor CDF - Lake sites (218,000 cubic yards)($000)

	Plan			
	9A-1	9A-2	9B-1	9B-2
CDF construction	$ 4,052	$ 5,119	$ 3,914	$ 3,234
E&D and S&A	648	819	626	518
Interest during construction	172	217	166	137
Real Estate	0	0	0	0
sub total	4,872	6,155	4,706	3,889
Dredging	2,529	2,529	2,529	2,529
Total	7,401	8,684	7,235	6,418
Cost per cubic yard of dredged material	$ 34.00	$ 39.75	$ 33.25	$ 29.50

f. Environmental and Social Impacts:

Since these four CDF plans are proposed for the same site and vary only in shape and size, their environmental impacts will be relatively equal. The significant adverse environmental impacts of maintenance dredging and CDF construction/operation would be: 1) a temporary increase in turbidity during dredging and construction, and 2) loss of about 15 acres of aquatic habitat through conversion to landfill. The principal adverse impact of the no-action plan would be the hindrance to navigation resulting from accumulation of sediment in the Federal channel and the potential for continued PCB contamination of Lake Michigan.

6. COST ALLOCATION

All costs for construction of the proposed confined disposal facility at Waukegan Harbor are attributed to federal environmental and water quality regulations and as such are a Federal responsibility.

7. PLAN IMPLEMENTATION

If a plan is authorized for construction, the Corps of Engineers will require that a local entity with legal and financial responsibility enter into an agreement to provide all necessary real estate and other items of local cooperation prior to construction.

a. Real Estate:

Prior to the date of advertisement for bids for construction of the facility, the local cooperator/s will be required to provide evidence of fee simple title to the submerged lands of Lake Michigan underlying the proposed Illinois facility. The submerged lands are presently owned by the State of Illinois. No relocation or acquisition as provided for under the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646 is anticipated.

b. Local Cooperation:

To provide for local assistance in connection with the construction, operation and maintenance of the proposed confined disposal facility (CDF) for Waukegan Harbor, the Chicago District will enter into an agreement with a non-Federal interest or interests in accordance with Section 221 of Public Law 91-611 which will act as local cooperator/s for the project. Such non-Federal interest/s will provide the required real estate interests; obtain the appropriate state and local permits; facilitate any other necessary coordination with the State of Illinois; receive possession of the CDF after it is filled; and assume the required maintenance responsibilities thereafter. The items of local cooperation are summarized below:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction, operation and maintenance of the facility;

b. Hold and save the United States free from damages due to the construction, operation and maintenance of the facility, except damages due to the fault or negligence of the United States or its contractors;

c. Maintain the facility after completion of its use for disposal purposes in a manner satisfactory to the Chief of Engineers.

d. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, approved 2 January 1971, in acquiring lands, easements, and rights-of-way for construction and subsequent maintenance of the project and inform affected persons of the pertinent benefits, policies, and procedures in connection with said act.

e. Comply with the Section 601 of Title VI of the Civil Rights Act of 1964 (Public Law 88-352) and Department of Defense Directive 5500.11 issued pursuant thereto and published in Part 300 of Title 32, Code of Federal Regulations, in connection with the maintenance and operation of the project.

f. The non-federal interests, or interests shall retain title to all real estate interests furnished by it pursuant to paragraph a. above. However, the confined disposal facility contemplated herein may be conveyed to another party only after completion of the facility's use for disposal purposes and after the transferee agrees in writing to use or maintain the facility in a manner which the Chief of Engineers determines to be satisfactory.

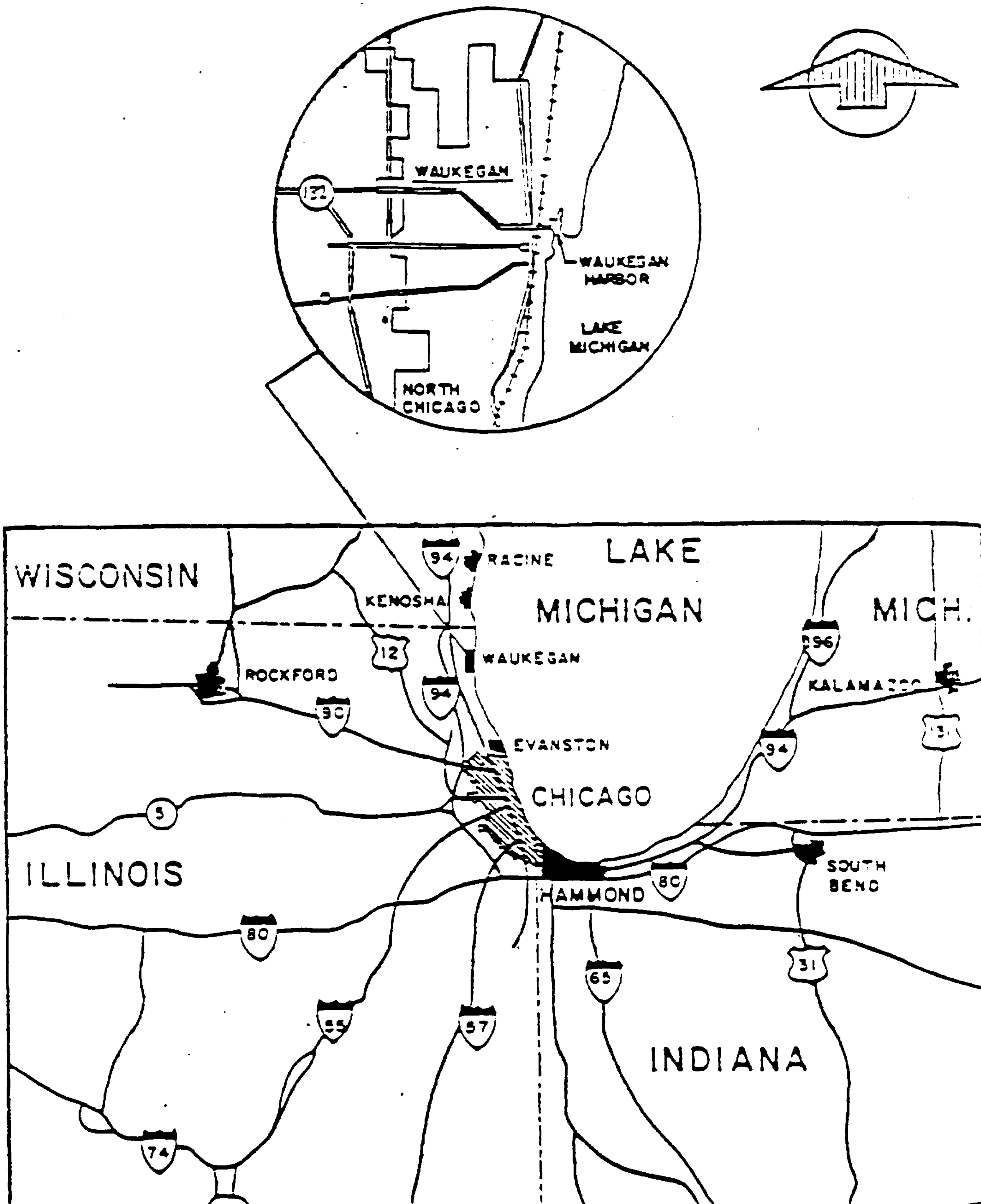
8. CONCLUSIONS.

a. Lake Sites:

Based on the costs of the alternative lake sites considered, plan 9B-2 is the least costly and therefore the most cost effective. There is little difference in the environmental and social impacts of the considered plans, and so plan 9B-2 is the tentatively selected plan. A local sponsor must be identified if this plan is to be implemented.

b. Previously Considered Sites:

The three sites identified in the April 1984 Site Selection Study have not been dropped from consideration. However, a local sponsor must be found if any of these sites is to be eventually implemented.

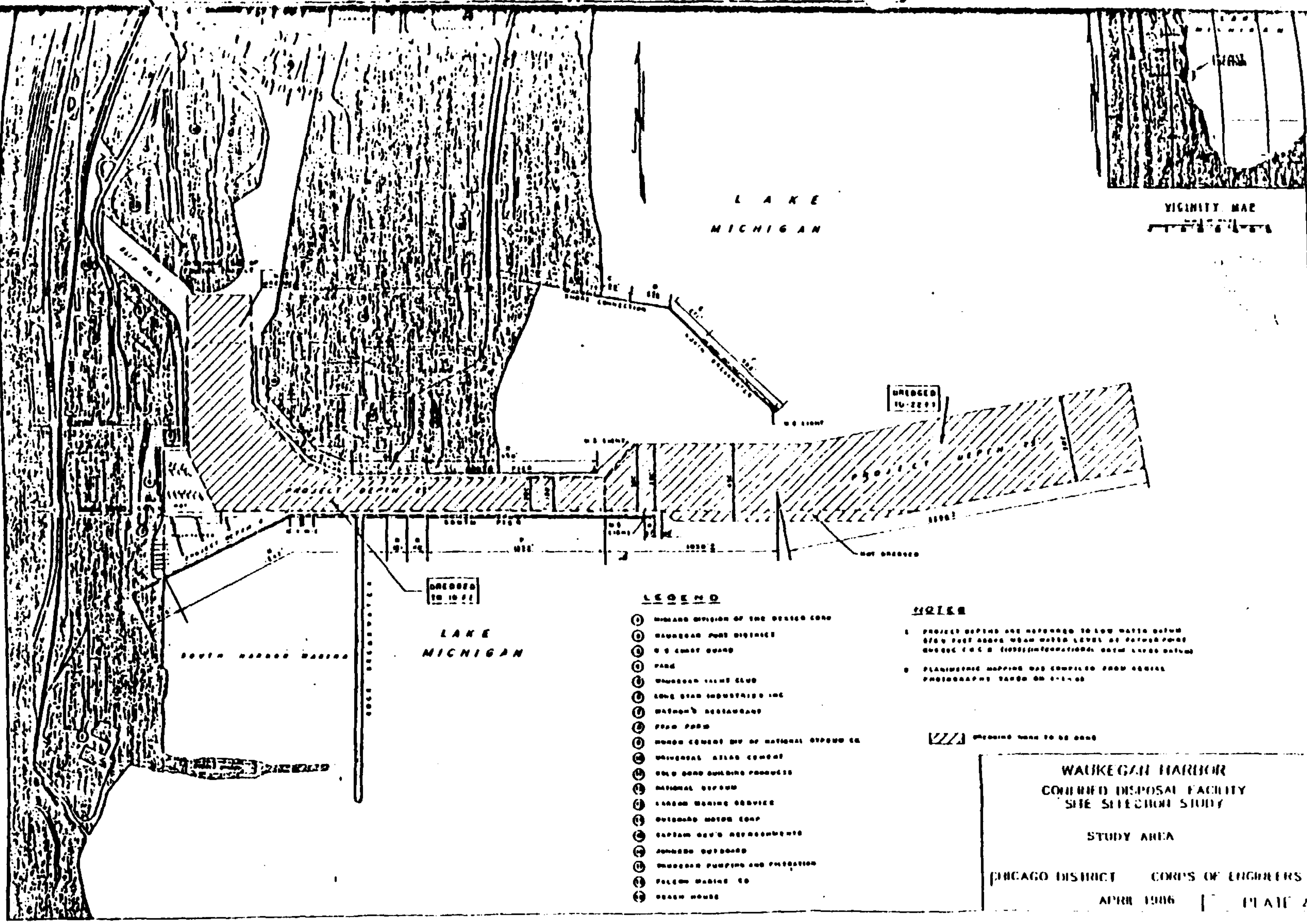


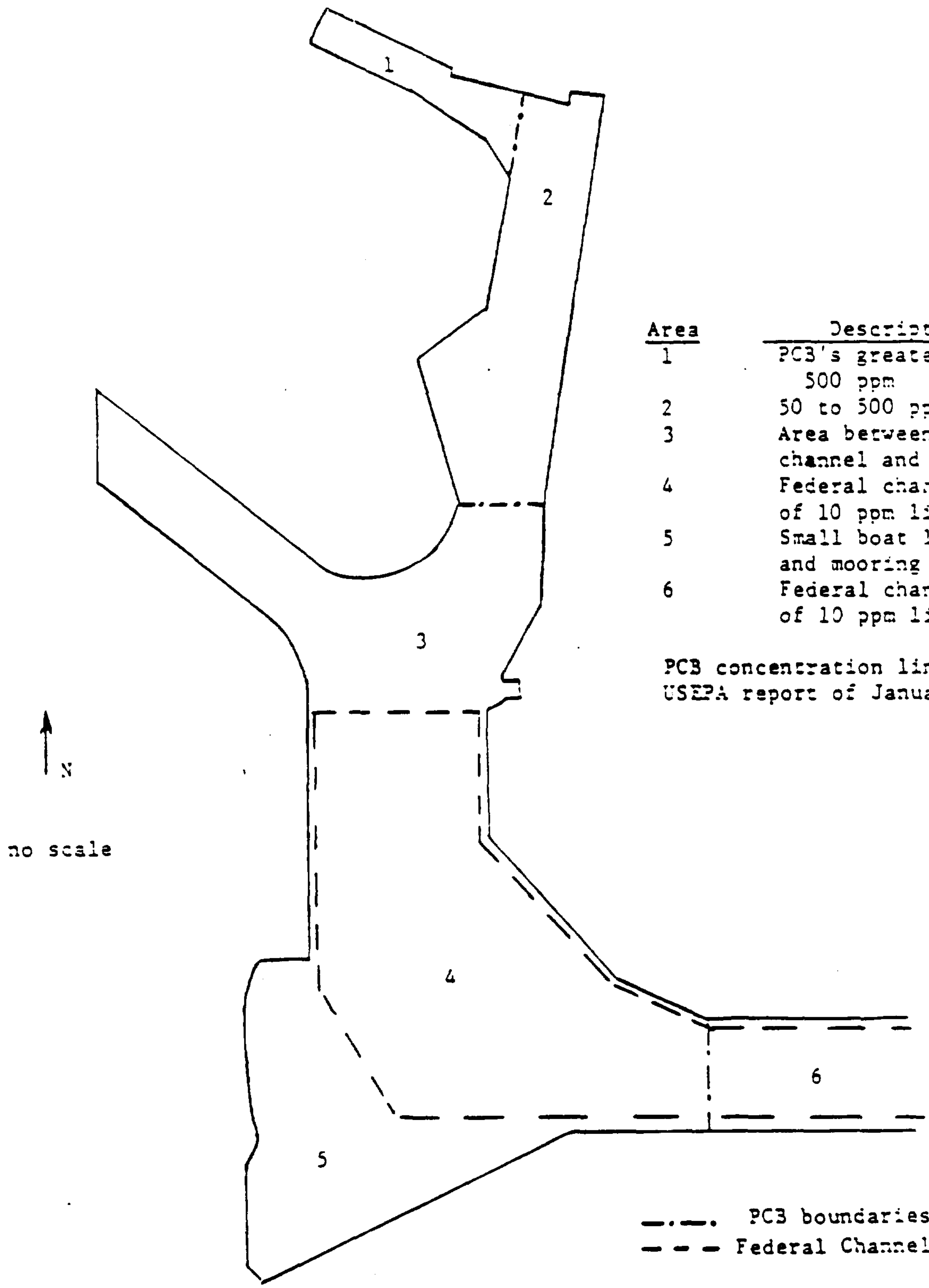
WAUKEGAN HARBOR

CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY

VICINITY MAP

CHICAGO DISTRICT CORPS OF EN


LAKE MICHIGAN
VICINITY MAP
LAKE MICHIGAN
LEGEND
NOTES
WAUKEGAN HARBOR
CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY
STUDY AREA
CHICAGO DISTRICT CORPS OF ENGINEERS
APRIL 1986
PLATE 2



Area	Description
1	PCB's greater than 500 ppm
2	50 to 500 ppm
3	Area between federal channel and 50 ppm line
4	Federal channel west of 10 ppm line
5	Small boat launching and mooring area
6	Federal channel east of 10 ppm line

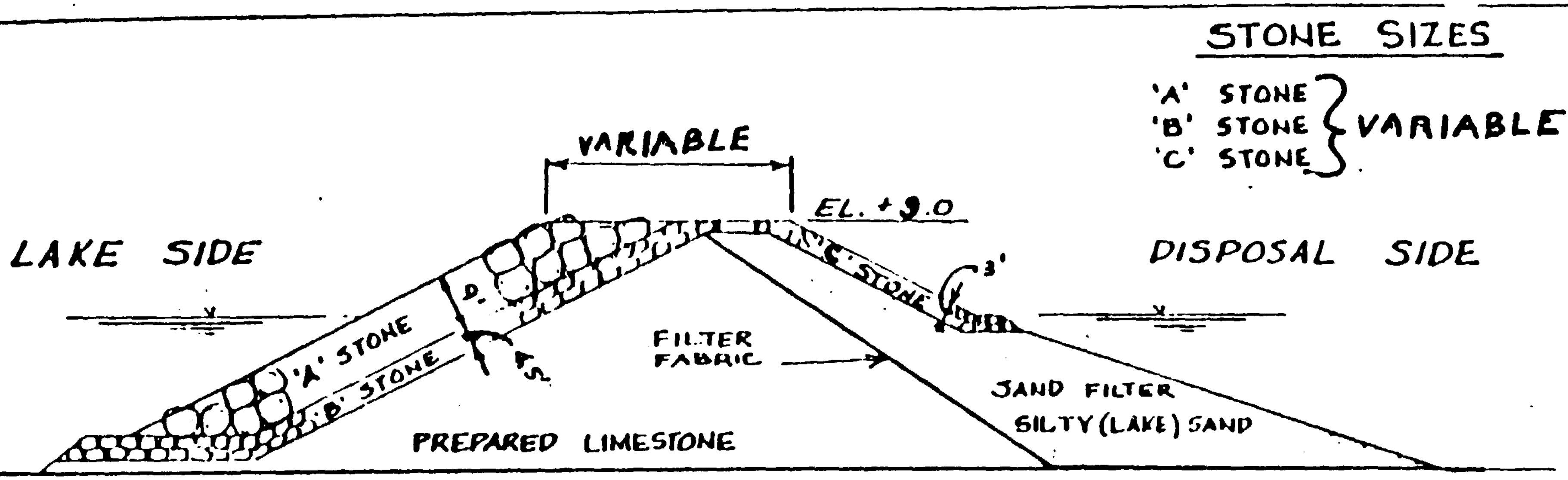
PCB concentration lines from USEPA report of January 1981.

WAUKEGAN HARBOR
CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY

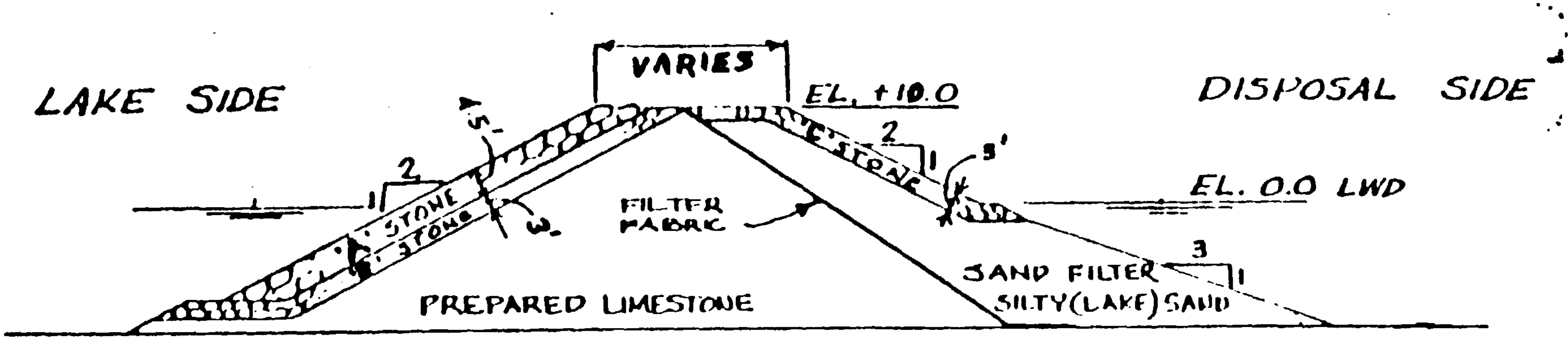
PCB-Contaminated Area
Location Map

CHICAGO DISTRICT CORPS OF ENGINEERS

APRIL 1986 PLATE



TYPICAL SECTION

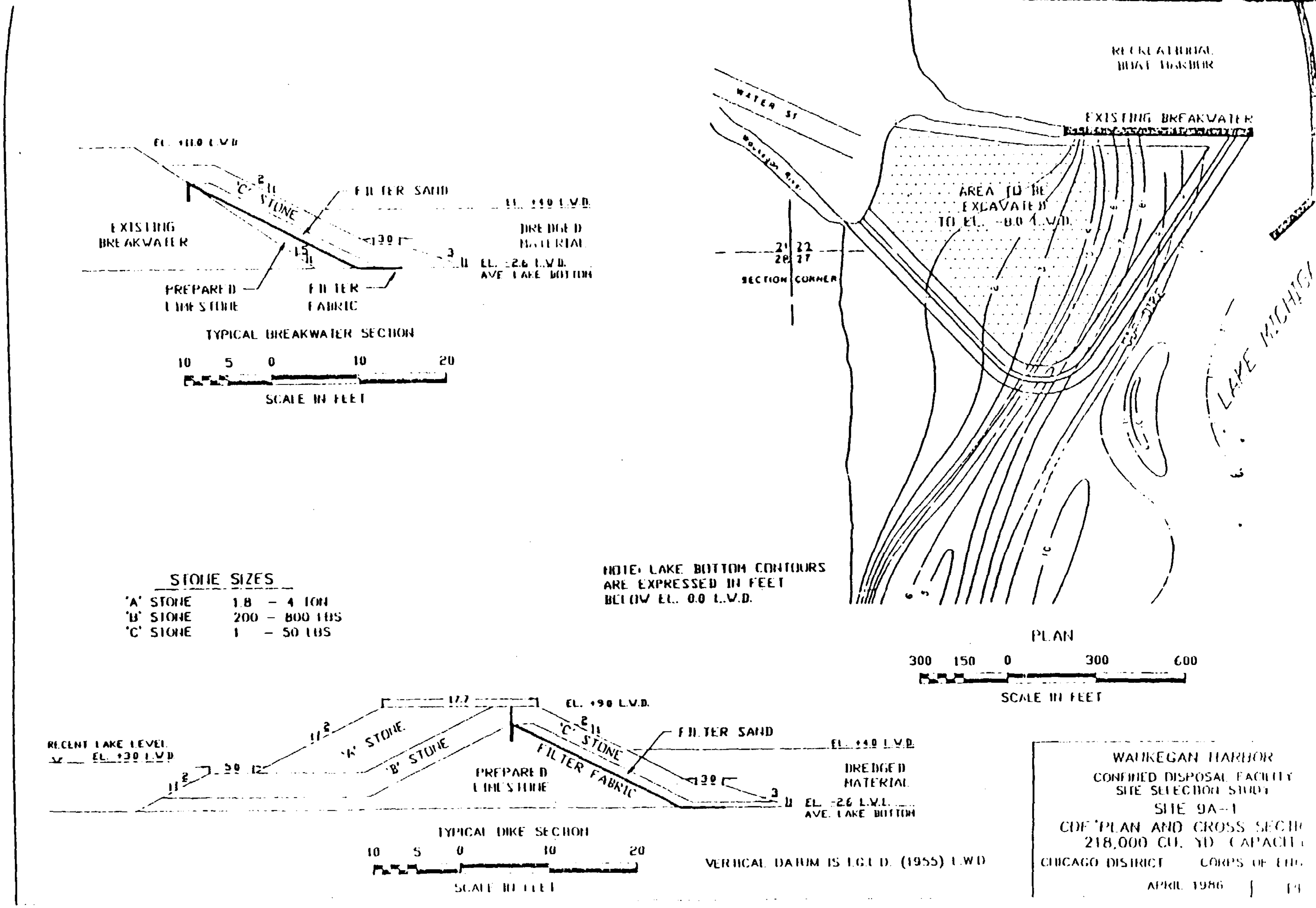


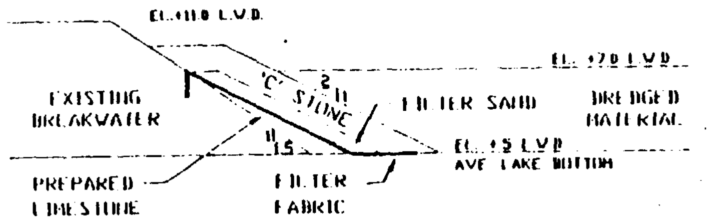
TYPICAL SECTION

WAUKEGAN HARBOR

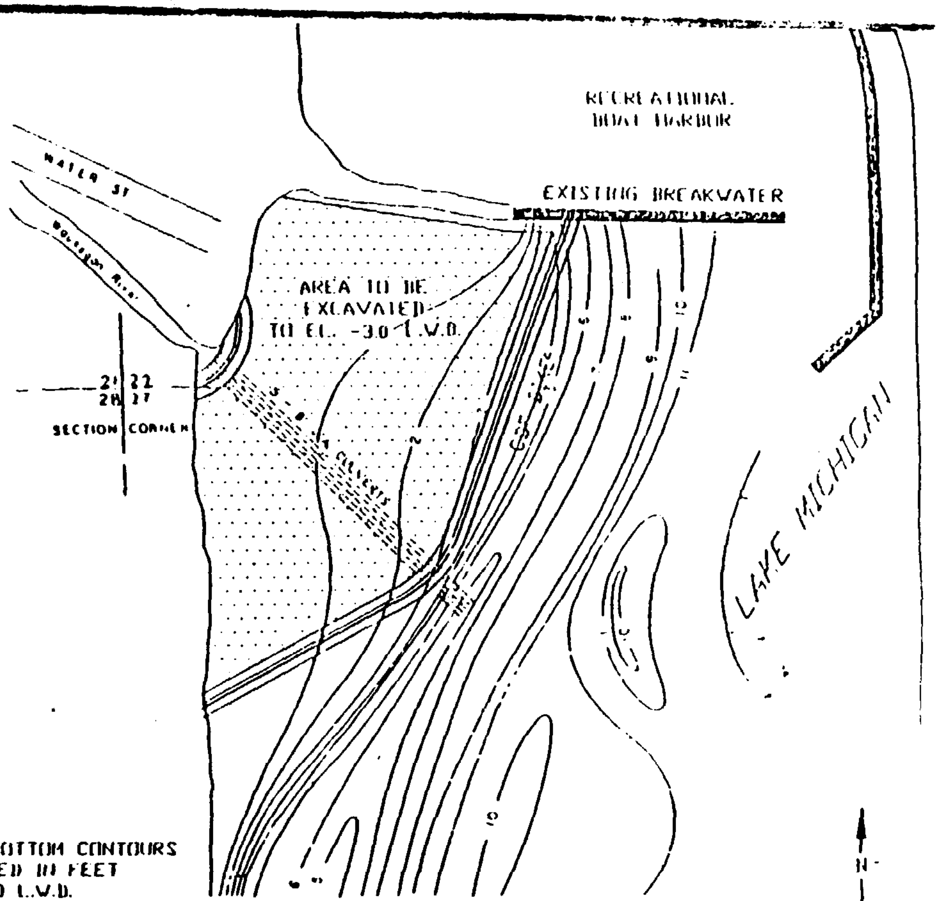
CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY

Breakwater/Dike
Typical Cross-Section


EL. +10.0 L.V.D.
'C' STONE
FILTER SAND
EL. +10 L.V.D.
EXISTING BREAKWATER
DREDGED MATERIAL
30
EL. -2.6 L.V.D. AVE. LAKE BOTTOM
PREPARED LIMESTONE
FILTER FABRIC
TYPICAL BREAKWATER SECTION
10 5 0 10 20
SCALE IN FEET
RECREATIONAL BOAT HARBOR
WATER ST
EXISTING BREAKWATER
AREA TO BE EXCAVATED TO EL. -8.0 L.V.D.
SECTION CORNER
LAKE MICHIG
NOTE: LAKE BOTTOM CONTOURS ARE EXPRESSED IN FEET BELOW EL. 0.0 L.V.D.
PLAN
300 150 0 300 600
SCALE IN FEET
STONE SIZES
'A' STONE 1.8 – 4 TON
'B' STONE 200 – 800 LBS
'C' STONE 1 – 50 LBS
RECENT LAKE LEVEL EL. +3.0 L.V.D.
17.2
EL. +9.0 L.V.D.
'A' STONE
'B' STONE
'C' STONE
FILTER SAND
FILTER FABRIC
PREPARED LIMESTONE
EL. +4.0 L.V.D.
DREDGED MATERIAL
EL. -2.6 L.V.D. AVE. LAKE BOTTOM
TYPICAL DIKE SECTION
10 5 0 10 20
SCALE IN FEET
VERTICAL DATUM IS I.G.L.D. (1955) L.W.D.
WAUKEGAN HARBOR
CONFINED DISPOSAL FACILITY SITE SELECTION STUDY
SITE 9A-1
CDF PLAN AND CROSS SECTIO
218,000 CU. YD. CAPACITY
CHICAGO DISTRICT CORPS OF ENG.
APRIL 1986



TYPICAL BREAKWATER SECTION

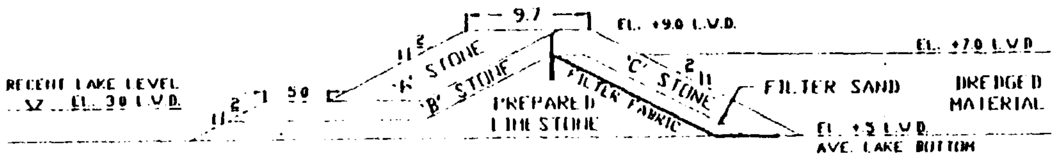


NOTE: LAKE BOTTOM CONTOURS ARE EXPRESSED IN FEET BELOW EL. 0.0 L.V.D.

PLAN

STONE SIZES

'A' STONE	700 -- 1500 LBS
'B' STONE	25 - 150 LBS
'C' STONE	1 - 50 LBS

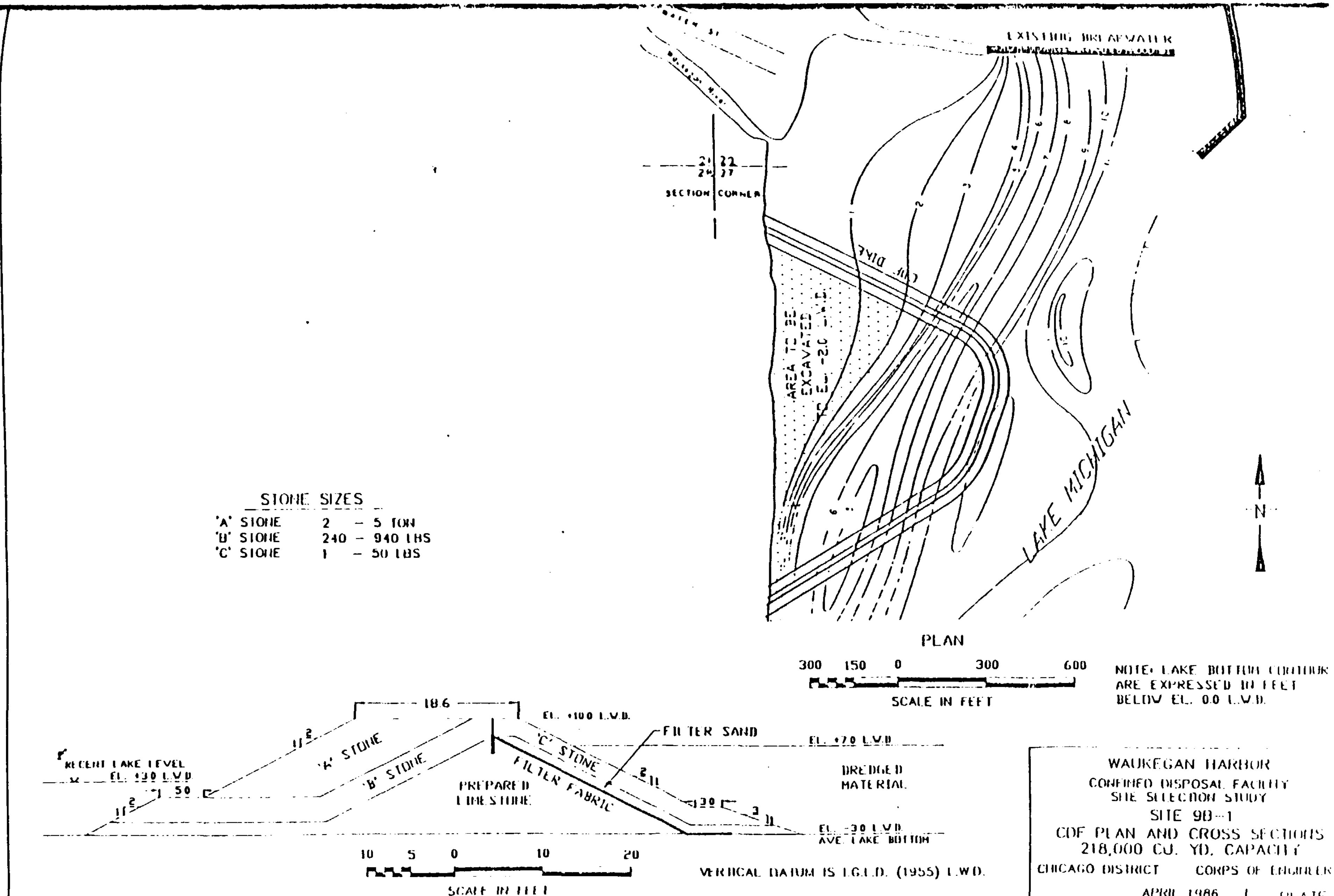


VERTICAL DATUM IS I.G.L.D. (1955) L.W.D.

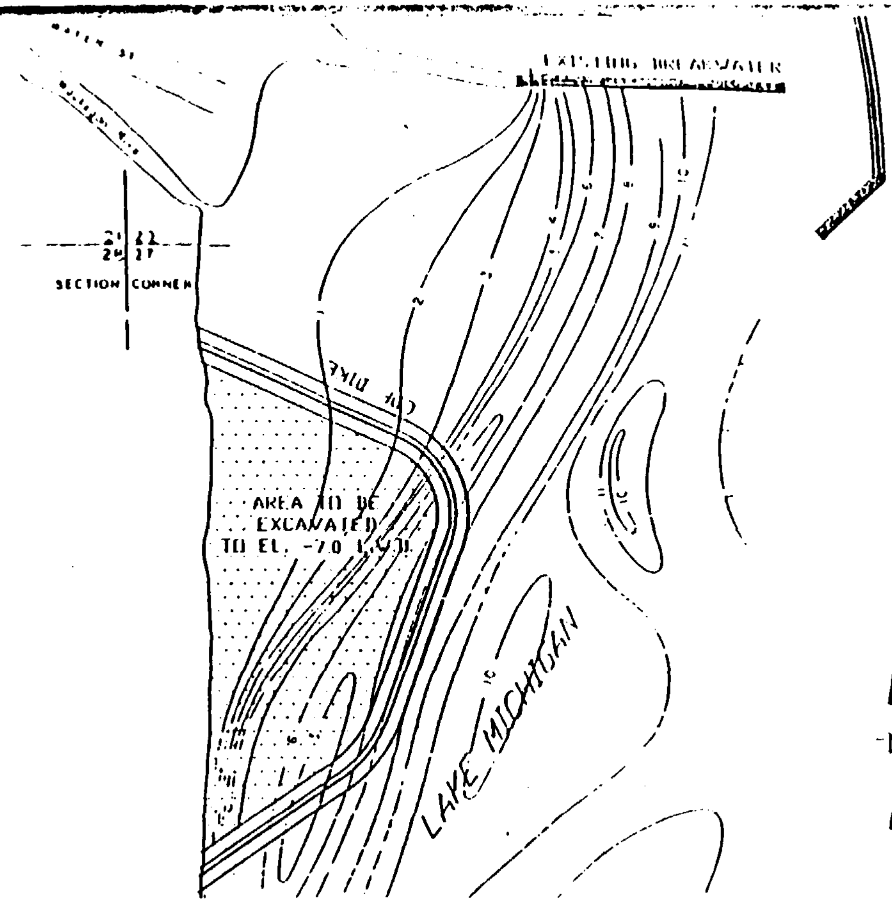
WAUKEGAN HARBOR
CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY
SITE 9A-2
CDF PLAN AND CROSS SECTIONS
218,000 CU. YD. CAPACITY

CHICAGO DISTRICT CORPS OF ENGINEERS

APRIL 1986 | PLATE



WAUKEGAN HARBOR
CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY
SITE 9D-1
CDF PLAN AND CROSS SECTIONS
218,000 CU. YD. CAPACITY
CHICAGO DISTRICT CORPS OF ENGINEERS
APRIL 1986 | PLATE



PLAN

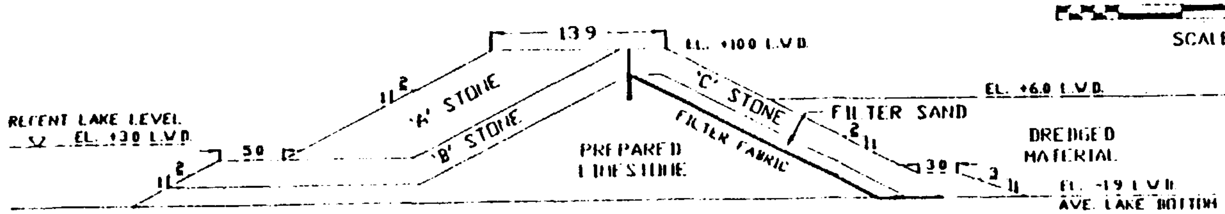
300 150 0 300 600

SCALE IN FEET

NOTE: LAKE BOTTOM CONTOURS ARE EXPRESSED IN FEET BELOW EL. 0.0 L.W.D.

STONE SIZES

'A' STONE	1800 LBS – 2 TON
'B' STONE	100 – 400 LBS
'C' STONE	1 – 50 LBS



10 5 0 10 20

SCALE IN FEET

VERTICAL DATUM IS I.G.L.D. (1955) L.W.D.

WAUKEGAN HARBOR
CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY
SITE 9B-2
CDF PLAN AND CROSS SECTIONS
218,000 CU. YD. CAPACITY

CHICAGO DISTRICT CORPS OF ENGINEERS

APRIL 1986 | PLATE

WAUKEGAN HARBOR, ILLINOIS

CONFINED DREDGED MATERIAL
DISPOSAL FACILITY

SITE SELECTION STUDY
Supplement

Attachment 1

COASTAL ENGINEERING

TABLE OF CONTENTS (Cont'd)

TABLES

FIGURES

PLATES

1. Define Project. Waukegan Harbor, the location of the proposed confined disposal facility (CDF), is located in north eastern Illinois (Lake County) on the west shore of Lake Michigan, about 35 miles north of Chicago and 16 miles north of North Chicago and 16 miles south of Kenosha, Wisconsin (Plate 1). The Waukegan CDF will be a diked retaining structure for containment of polluted dredged materials from the Federal navigation channel at Waukegan Harbor. Since it is located in Lake Michigan, the structure was designed to withstand the local wave climate. Four alternative plans for the CDF have been developed. See Plates 2 thru 5.

2. Design of Alternative Plans.

2.1 Bottom Depths. Using the bottom contours on Plates 2 thru 5, bottom depths were found for each of the four alternative plans. Plan 9A-1 would be built at approximately 9 feet below Low Water Datum (LWD), plan 9A-2 at -3 feet LWD, plan 9B-1 at -10 feet LWD, and plan 9B-2 at -6 feet LWD.

2.2 Design Wave Conditions for Stone. The stone for the outer layers are designed to withstand a storm condition with a 200 year return period.

2.3 Design Water Level. The design water level has a 20 year return period. Taken from Reference 1, that level is 5.0 feet above LWD. The current water level is close to this design water level.

2.4 Design Deepwater Wave Height. The design wave height has a 10 year return period. This value is taken from a publication (reference 2) that contains hind cast wave information for Lake Michigan. Historical wind data from six stations along Lake Michigan served as input to a numerical hind cast model. The model determined deepwater significant wave heights and mean significant periods for each wave height. The deepwater design wave at Waukegan is 17.4 feet with a 9.6 second period from the North-Northeast and 11.8 feet, 7.5 seconds from the South to Southeast.

2.5 Design Wave Height at Structure. The deepwater wave is reduced as it approaches shore. The design wave heights for stone sizing at the structure are calculated using surf zone wave decay relationships. These were developed by a man named Goda (Reference 3). Figure 1 was developed from reference 3. Table 1 gives a summary of design parameters. Table 2 shows the design wave height computations.

Table 1
Summary of Design Parameters

Plan	Direction Critical Waves	Deepwater Wave Ht. (Ho',ft)	Wave Period (T,sec)	Design Water Level (SWL, +ft LWD)	Bottom Elevation (btm, -ft LWD)	Total Design Water Depth (h, SWL +btm,ft)
9A1	N-NE	17.4	9.6	5	9	14
9A2	S-SE	11.8	7.5	5	3	8
9B1	N-NE	17.4	9.6	5	10	15
9B2	N-NE	17.4	9.6	5	6	11

Table 2
Design Wave Ht for Stone Computations
(See Figure 1)

Plan	Offshore Slope(m)	h/Ho'	Lo ($5.12T^2$,ft)	Ho'/Lo	$H_{1/3}/Ho'$	Design Wave Ht ($H_{1/3}$,ft)
9A1	.002	.81	471.9	.04	.52	9.1
9A2	.002	.67	284.9	.04	.45	5.3
9B1	.002	.86	471.9	.04	.55	9.5
9B2	.002	.63	471.9	.04	.42	7.3

2.6 Stone Sizes Computations. The stone placed on the outside of dike structure, armor stone, needs to be a certain weight in order to resist movement and displacement under design wave conditions. The following equation calculates that weight:

$$W = \frac{W_r H^3}{K_d (S_r - 1)^3 \cot \theta} \qquad \text{(Equation 7-116, SPM, reference 4)}$$

where:

W_r = unit weight of armor stone = 165 lbs/ft^3
H = design wave height in feet
S_r = $\frac{W_r}{W_w}$ = $\frac{\text{unit weight of rock}}{\text{unit weight of water}}$ = $\frac{165}{62.4}$ = 2.64
$\cot \theta$ = angle of structure slope = 2
K_d = stability coefficient (Table 7-8 SPM) = 3.5
W = weight of individual armor stone in pounds

The armor stone is allowed to range between 90% and 200% of this weight. The secondary stone layer, placed under the armor units, is one tenth of the weight of the armor stone. This stone may vary between 50% to 200% of the secondary stone weight. The core and bedding stone is a prepared stone with a very wide gradation.

2.7. Stone Thickness. The recommended thickness of the armor and secondary stone thickness is about two stones. The crest width is normally no less than three units. These values are determined using the following equation:

$$r = nk (W/W_r)^{1/3} \qquad \text{(SPM, reference 4)}$$

where:

n = number of layers (2 for computing layer thickness and 3 for computing crest width)
k = layer coefficient = 1
W = typical armor weight
W_r = unit weight of stone = 165 lbs/ft^3
r = layer thickness

2.8 Stone Size and Thickness for the Plans. Table 3 summarizes the results of the stone sizing computations.

Table 3
Stone Weights and Thicknesses

	Armor Units				Secondary Layer		
H1/3 (ft)	W (lbs)	Range of Units (.9W-2W, lbs)	Layer Thickness (B, ft)	Crest Width (B, ft)	W/10 (lbs)	Range of Units (.5W/10-2W/10, lbs)	Layer Thickness (B, ft)
[illegible]	4000	3600-8000	5.7	≥ 8.6	400	200-800	2.7
[illegible]	740	700-1500	3.3	≥ 4.9	74	25-150	1.5
[illegible]	4700	4200-9400	6.0	≥ 9.1	470	240-940	2.8
[illegible]	2000	1800-4000	4.5	≥ 6.8	200	100-400	2.1

2.9 Determining Crest Elevations. An adequate crest elevation would not allow backwash. Backwash would occur if water continued to overtop. The CDF after the available volume was filled and discharged back to the lake. This CDF will be filled and capped in one dredging season. Thus, backwash is only a possibility for one dredging season. The design criteria were determined with this dredging schedule in mind. These include:

- Design water depth of +4.0 feet LWD (20% chance of exceedence)
- Wave period of 7.28 seconds from N-NE and 5.8 seconds from S-SE.
- Design storm wind velocity of 31 mph (45.5 ft/sec.) from the N-NE and S-SE.
- Design storm duration of 24 hours.

For the overtopping analysis, a state-of-the-art methodology is applied. Initially monochromatic wave theory was used exclusively. It is now generally accepted that an irregular wave approach is preferred. Using Reference 5, "Summary and Applications of the TMA Shallow Water Spectrum", shallow water spectral form waves are used in crest elevation designs rather than monochromatic wave trains.

2.10 Design Wave Heights for Crest Elevations. Using the design criteria, the maximum probable wave height is calculated. This will be the basis for the overtopping design wave. This is done by calculating the depth limited significant wave height (H_{mo}). Since the proposed CDF will be located in intermediate to shallow water depths, the following series of equations are used to calculate H_{mo} (reference 5):

H_{mo} = depth limited wave height

$$= \frac{1}{\pi} (\alpha g h)^{1/2} T_m$$

where

α, κ = shape factors for spectral wave energy density distribution

$$\alpha = 0.0078\kappa^{0.49}$$

$$\kappa = \frac{U^2}{g} k_m$$

U = windspeed at 10 m elevation

g = acceleration of gravity

$k_m = 2\pi/L_m$ = wave number for waves at peak frequency

L_m = wavelength associated with peak frequency f_m from linear wave theory

$= (gh)^{1/2} T_m$ in shallow water

T_m = wave period

h = depth of water

Then using Figure 2, the significant wave height (average of the highest 1/3 waves) is calculated from H_{mo}. Table 4 shows the significant wave height computation results.

2.11 Crest Elevation Computations. The crest elevation of a CDF is determined by calculating wave runup, overtopping volumes and the time it takes to fill the available volume. The design storm has a duration of 24 hours. Any crest elevation that allows the available volume to fill during design storm conditions in less than 24 hours is not acceptable. That would allow water to backwash into the lake. The available volume is smallest just before capping. Three or more feet of cover material is needed for capping. In order to optimize the design, fill times for a range of cap thicknesses (3 to 5 feet) were calculated.

TABLE 4

Design Wave Height for Crest Elevation Computations

Plan	Design Water Level (SWL, ft MLW)	Bottom elevation (btm, -ft MLW)	Total Design Water Depth (h, SWL+btm, ft)	Wave Period (Tm, sec)	Wave Length (Lm, ft)	Wind Speed (V, ft/sec)	K		Depth Limited Wave Length (Hm, ft)	Significant Wave Height (Hs) Figure 2: = h/gTm^2	Hs/Hm	Hs (ft)
9A1	4	9	13	7.28	148.9	45.5	2.71	.013	5.34	.0076	1.10	5.87
9A2	4	3	7	5.8	87.1	45.5	4.63	.017	3.57	.0065	1.13	4.03
9B1	4	10	14	7.28	154.6	45.5	2.54	.012	5.50	.0082	1.09	6.00
9B2	4	6	10	7.28	130.6	45.5	3.09	.014	4.92	.0058	1.15	5.66

2.12 Runup, Overtopping and Fill Times. The procedure used to determine how the CDF will fill is as follows:

- Calculate the wave height yielding the runup equal to the structure freeboard or in other words, the minimum wave height which will overtop structure.

- Determine the average wave height of all the waves whose runup reaches and exceeds the crest elevation and calculate the average probability of that wave occurring.

- Calculate the overtopping rate using the average wave height overtopping the structure.

- Since monochromatic waves are assumed in determining the overtopping parameters and only spectrum waves are considered, the overtopping rate must be multiplied by the probability of that wave height occurring.

Tables 5 and 6 show the computation results. From these results, recommended crest elevations and dredge fill elevations were selected.

3. Cross Sections. Plate 6 shows the proposed typical cross section for each alternative plan.

Average Wave Height Overtopping Structure

Plan	Crest Elv (C. Elv, +ft MLW)	Design Water Level (SWL, +ft MLW)	Freeboard (Crest Elv SWL, F, ft)	Run Up of Minimum overtopping wave (same as F, ft)	1/Wave Ht, overtopping structure, min (H_{min}, ft)	2/Wave Ht, significant (H_s, ft)	1/Wave Ht, Root mean square H_s/1.416 (H_{rms}, ft)	3/ H_{min}/H_{rms}	3/Probability (Curve a) P	3/H_{avg}/H_{rms} (curve b)	Wave Ht, overtopping structure, average (H_{avg}/ft)
	8	4	4	4	2.41	5.87	4.15	.58	0.70	1.09	4.52
9A1	9	4	5	5	3.15	5.87	4.15	.76	0.50	1.24	5.15
	10	4	6	6	4.0	5.87	4.15	.96	0.39	1.3	5.40
	8	4	4	4	2.75	4.08	2.88	.95	0.40	1.3	3.74
9A2	9	4	5	5	3.68	4.08	2.88	1.28	0.19	1.6	4.61
	10	4	6	6	4.55	4.08	2.88	1.58	0.10	1.78	5.13
	9	4	5	5	3.15	6.00	4.24	0.74	0.50	1.22	5.17
9B1	10	4	6	6	4.00	6.00	4.24	0.94	0.40	1.28	5.43
	11	4	7	7	4.83	6.00	4.24	1.14	0.28	1.48	6.28
	9	4	5	5	3.15	5.66	3.99	0.79	.42	1.25	4.99
9B2	10	4	6	6	4.00	5.66	3.99	1.00	.37	1.32	5.27
	11	4	7	7	4.83	5.66	3.99	1.21	.23	1.55	6.19

1/ See Figure 3
2/ Table 4
3/ See Figure 4

Table 6

Wave Run Up, Overtopping and Fill Time Computations

Plan	Crest Elv (C. Elv, feet MSL)	1/ Average Wave Ht overtopping structure (Havg, ft)	1/ Freeboard (F, ft)	2/ Wave Period (Tm, sec)	3/ Runup of Average Wave Ht overtopping structure (Ravg, ft)	Freeboard Divided by Runup F/Ravg	4/	4/ Q_0^*	5/ (Q cfs/lin. ft)	Linear footage exposed (ft)	Cap thickness (ft)	6/ Available volume X10^6 (ft^3)	Fill time ( )
											3	1.73	8
	8	4.52	4	7.28	6.59	0.61	.065	.0045	0.24	250	4	2.3	10.7
											5	2.88	13.3
											3	1.73	14.7
9A1	9	5.15	5	7.28	7.2	0.69	.065	.0045	0.131	250	4	2.3	19.5
											5	2.88	24.4
											3	1.73	36
	10	5.40	6	7.28	7.55	0.79	.065	.0045	0.052	250	4	2.3	49
											5	2.88	62
											3	1.70	8.8
	8	3.74	4	5.8	5.16	0.76	.052	.03	0.045	1200	4	2.27	11.7
											5	2.84	14.6
											3	1.7	26.7
9A2	9	4.61	5	5.8	6.08	0.82	.052	.03	0.0148	1200	4	2.27	35.5
											5	2.84	44.4
											3	1.7	202
	10	5.13	6	5.8	6.60	0.91	.052	.03	0.00195	1200	4	2.27	270
											5	2.84	337
											3	1.68	6.1
	9	5.17	5	7.28	7.33	0.68	.065	.0045	0.14	550	4	2.24	8.1
											5	2.81	10.1
											3	1.68	15.7
9B1	10	5.43	6	7.28	7.62	0.79	.065	.0045	0.084	550	4	2.24	20.9
											5	2.81	26.2
											3	1.68	24.3
	11	6.28	7	7.28	8.55	0.82	.065	.0045	0.036	550	4	2.24	32.4
											5	2.81	40.5
											3	1.37	6.5
	9	4.99	5	7.28	7.13	0.70	.06	.03	0.107	550	4	1.83	8.6
											5	2.28	10.8
											3	1.37	20.9
9B2	10	5.27	6	7.28	7.45	0.81	.06	.03	0.033	550	4	1.83	27.9
											5	2.28	34.9
											3	1.37	[illegible]
	11	[illegible]	7	7.28	[illegible]	[illegible]	.06	.03	[illegible]	[illegible]	4	[illegible]	[illegible]

8

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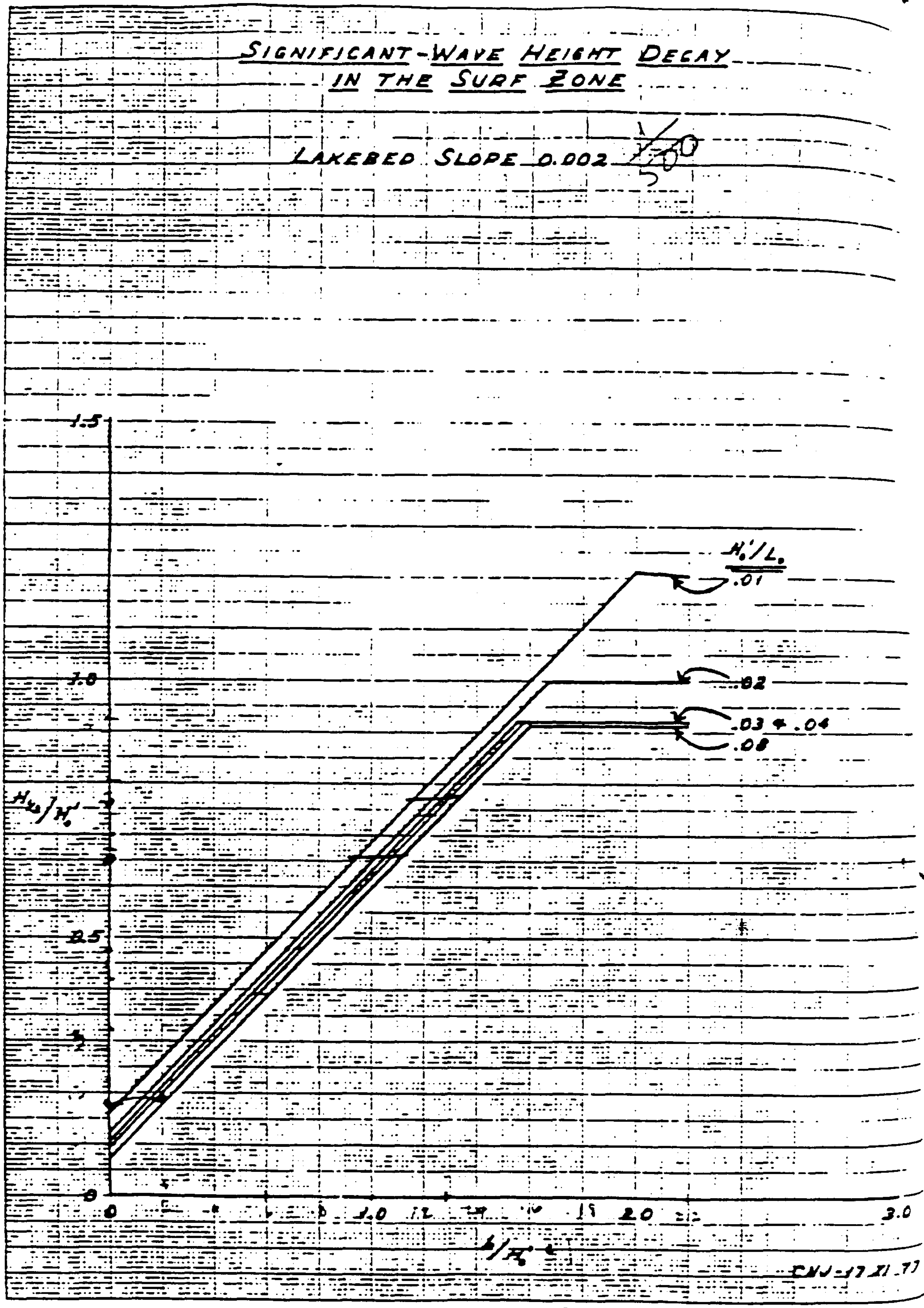


Figure 1. Nearshore Wave Height Computation, Goda Method

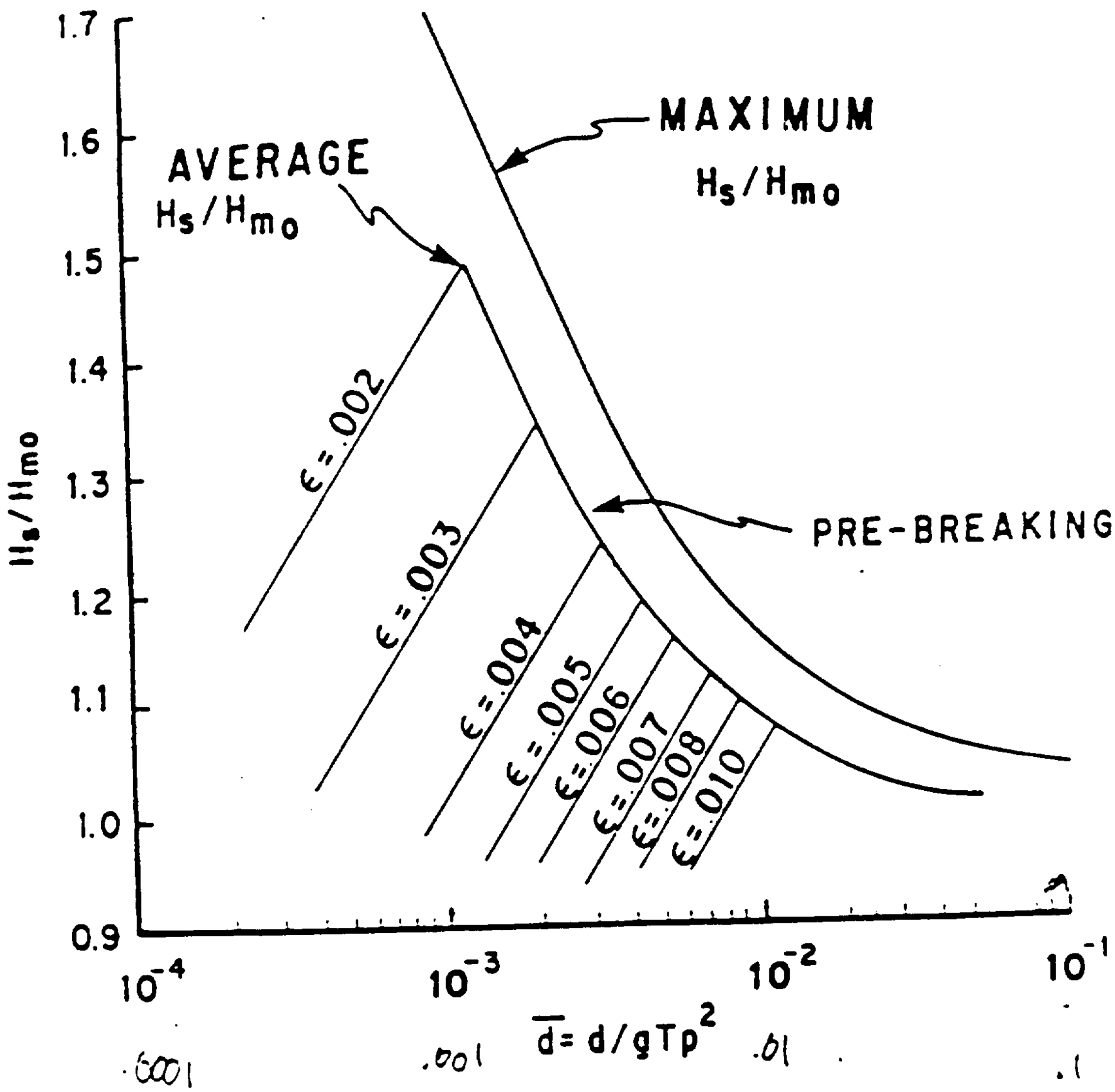


Figure 2. Maximum and average values of H_s/H_{mo} for irregular waves (from Thompson and Vincent 1985) (Reference 5)

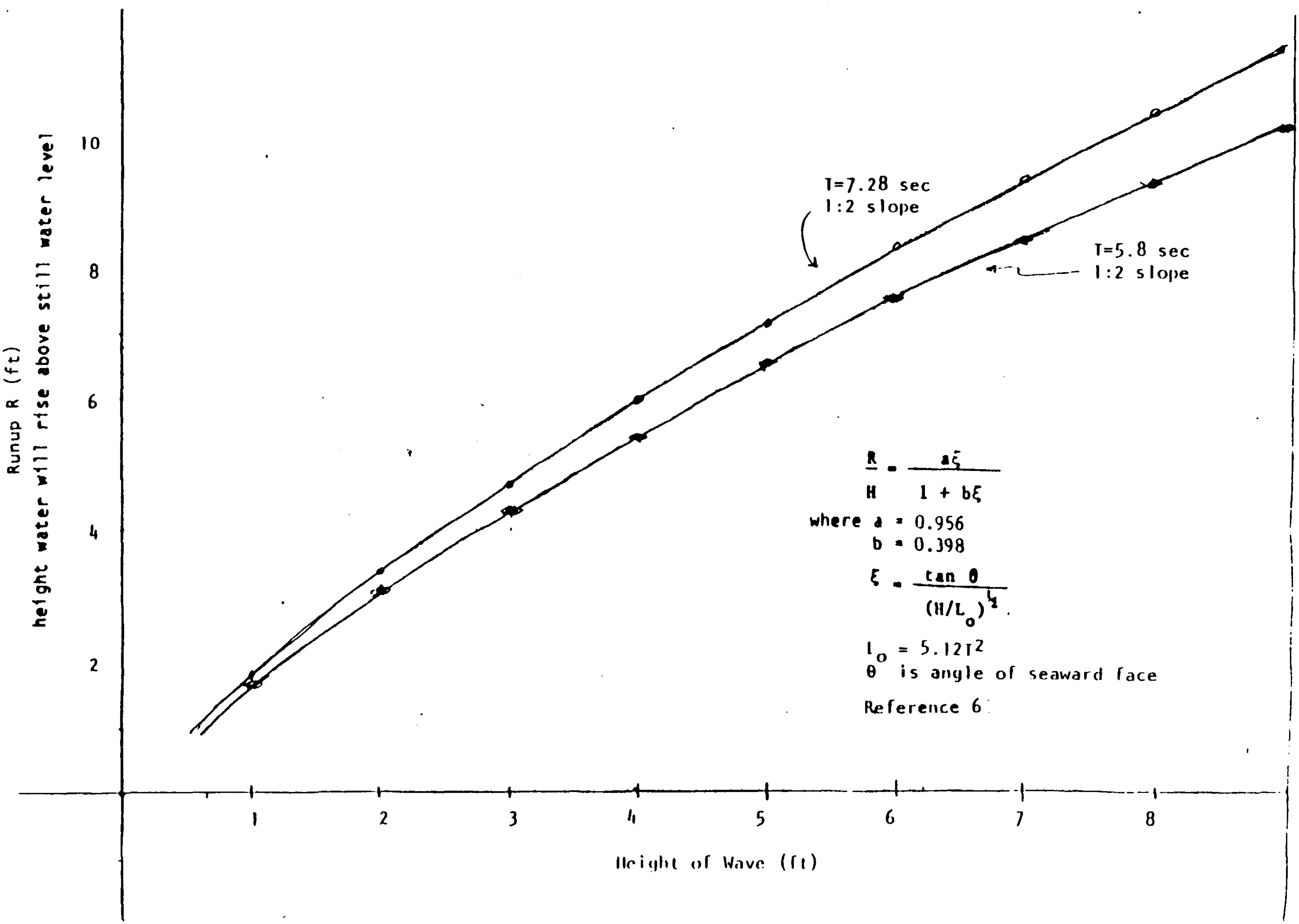


Figure 3. Wave Height Vs. Wave Runup on [illegible]

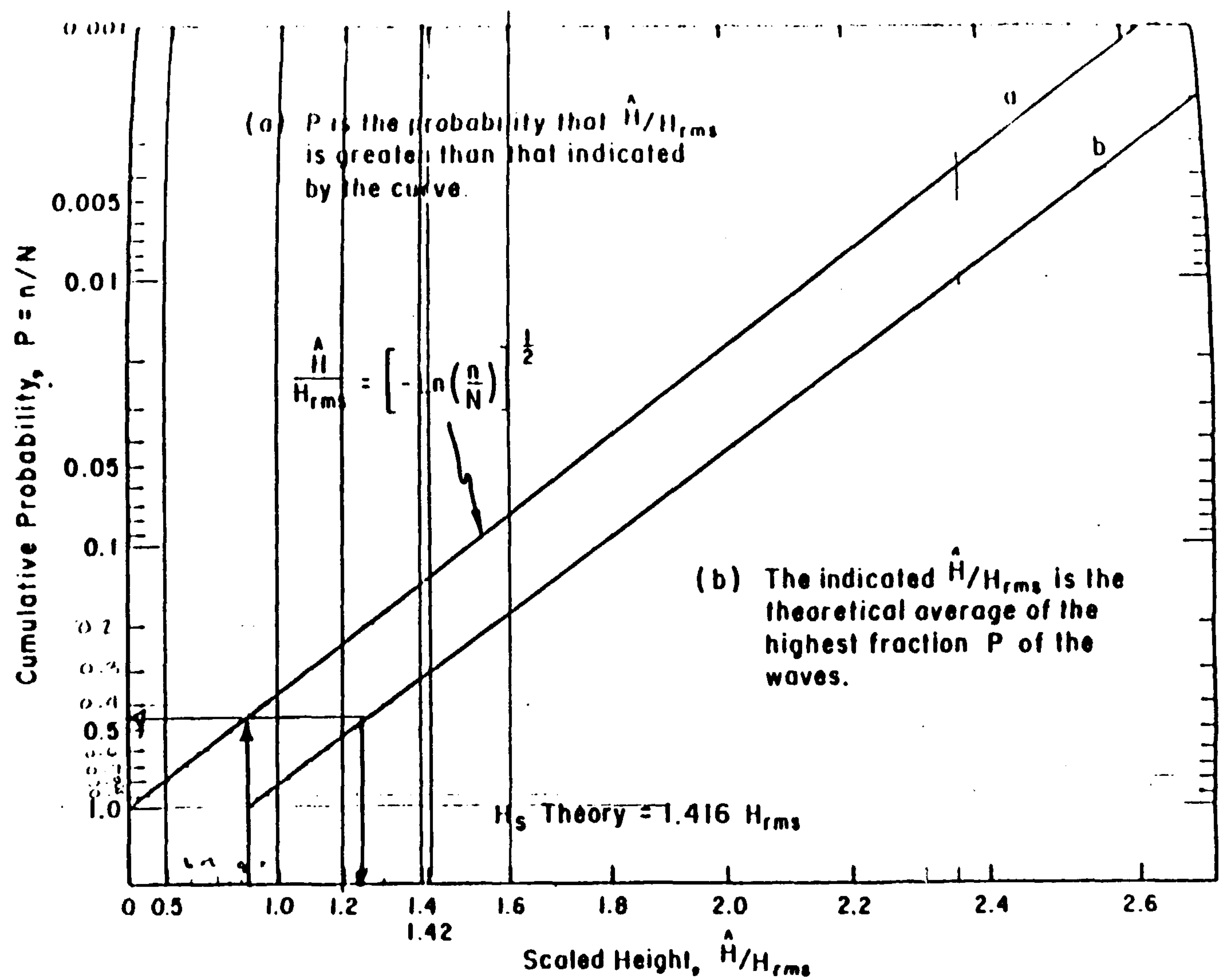


Figure 4. Theoretical wave height distributions. (Reference 4)

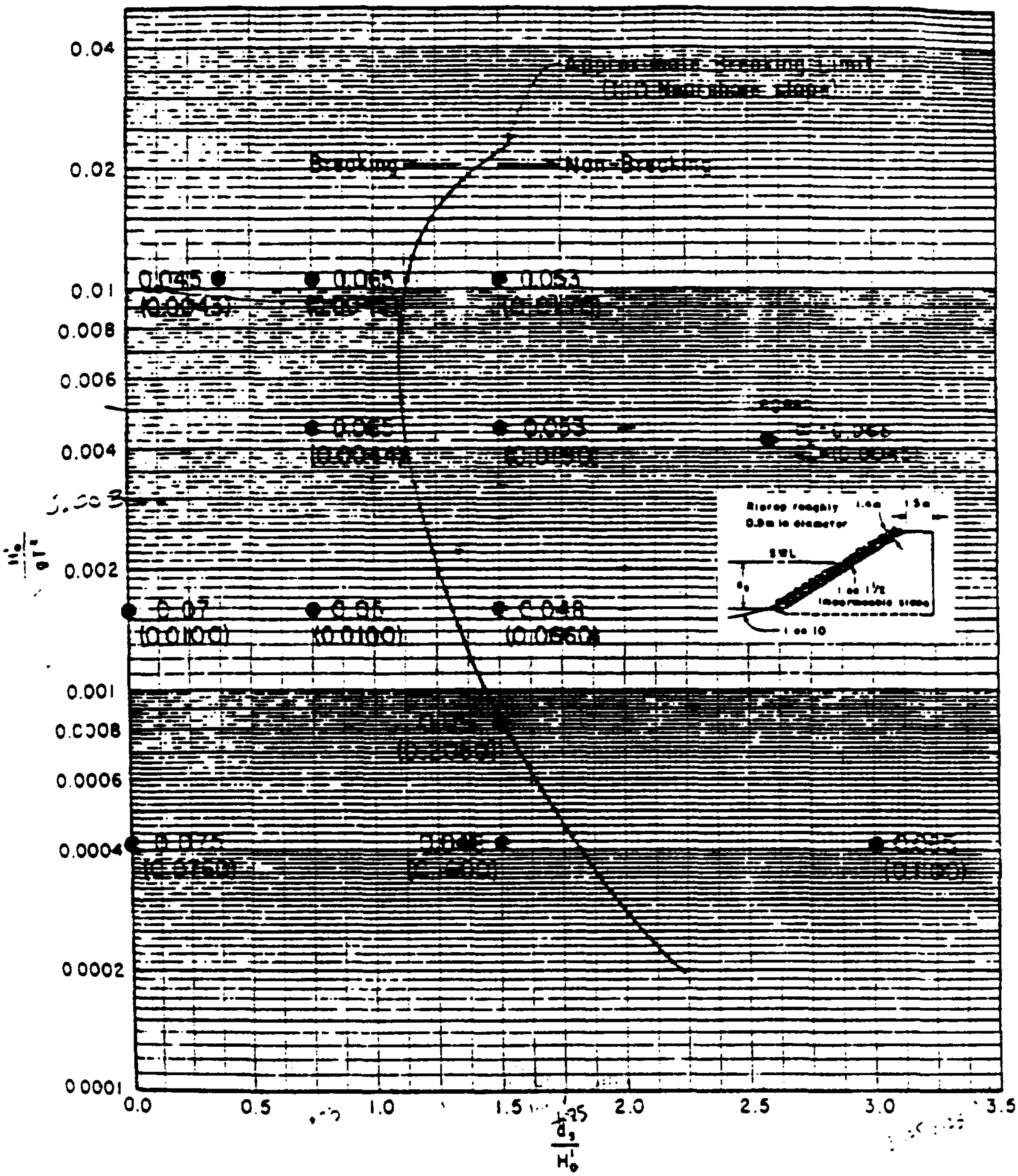
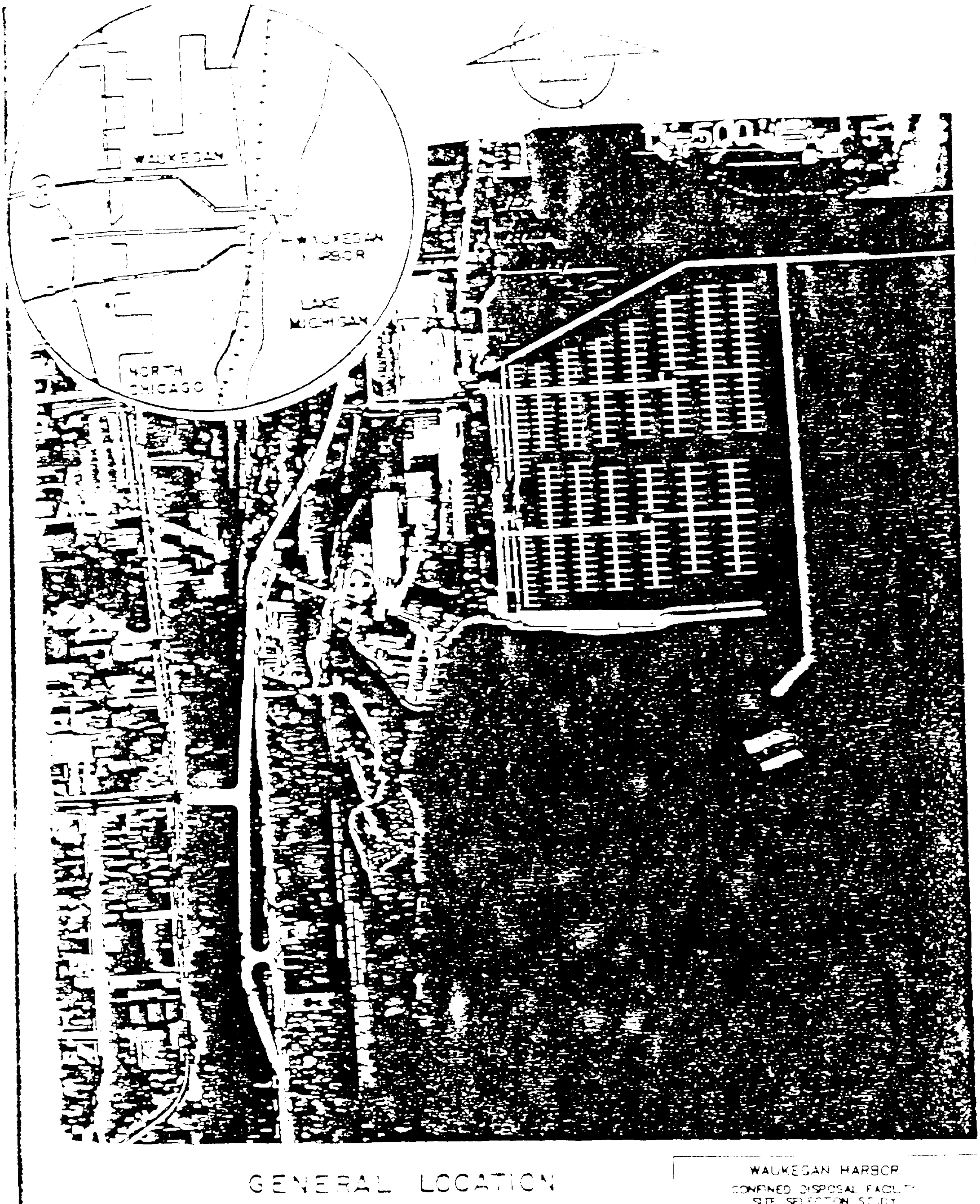


Figure 5. Overtopping parameters α and Q_0^* (riprapped 1:1.5 structure slope on a 1:10 nearshore slope). (Reference 4)



GENERAL LOCATION

1" = 500' SCALE

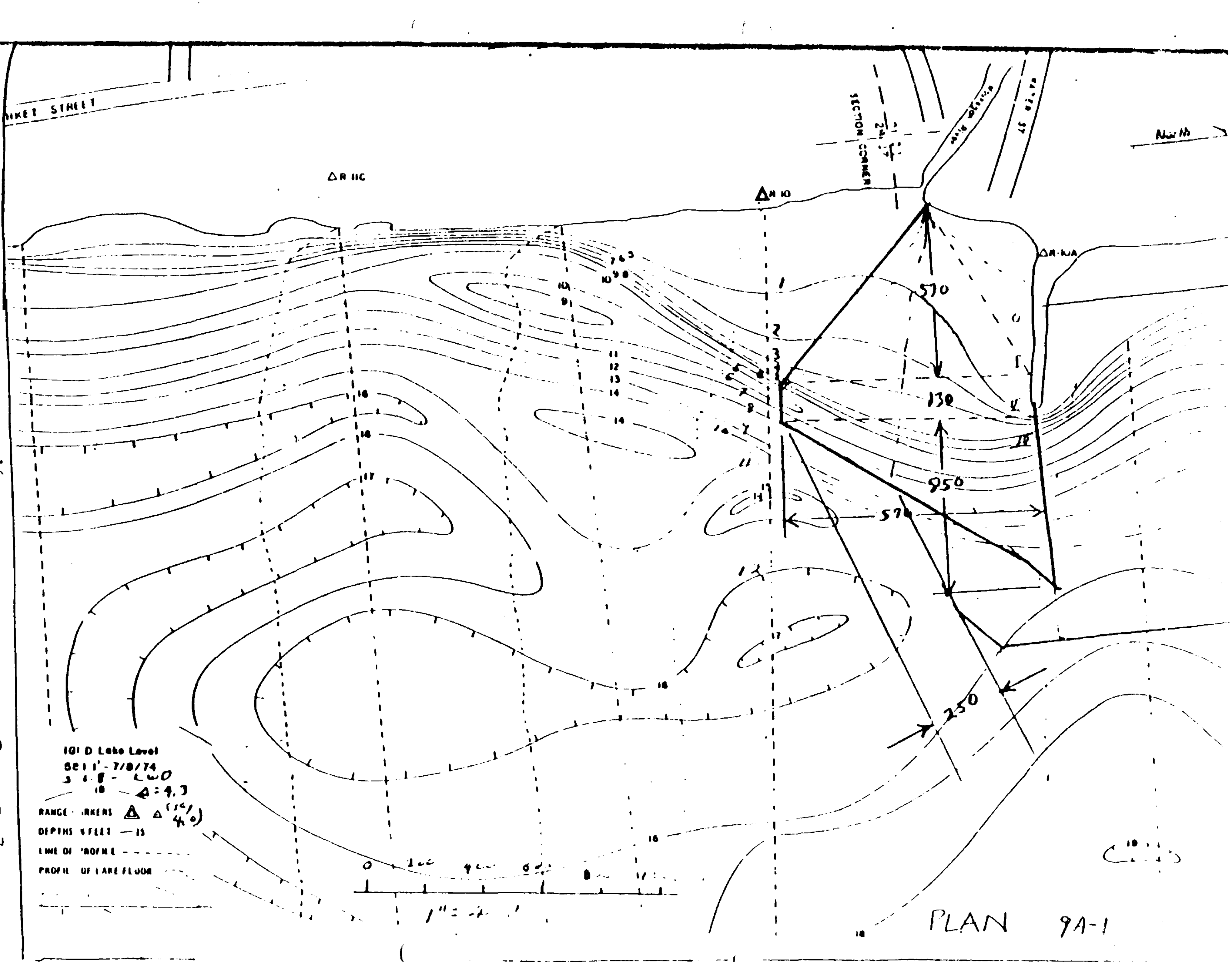
WAUKEGAN HARBOR
CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY

8,000 CU YD CAPACITY
CHICAGO DISTRICT CORPS OF ENGINEERS
APRIL 1986 1

NCCEO-H

PLATE 2

16



PLAN 9A-1
North
SECTION CORNER
STREET
101 D Lake Level
RANGE MARKERS
DEPTHS IN FEET — 15
LINE OF PROFILE
PROFILE OF LAKE FLOOR
570
130
950
570
250

17

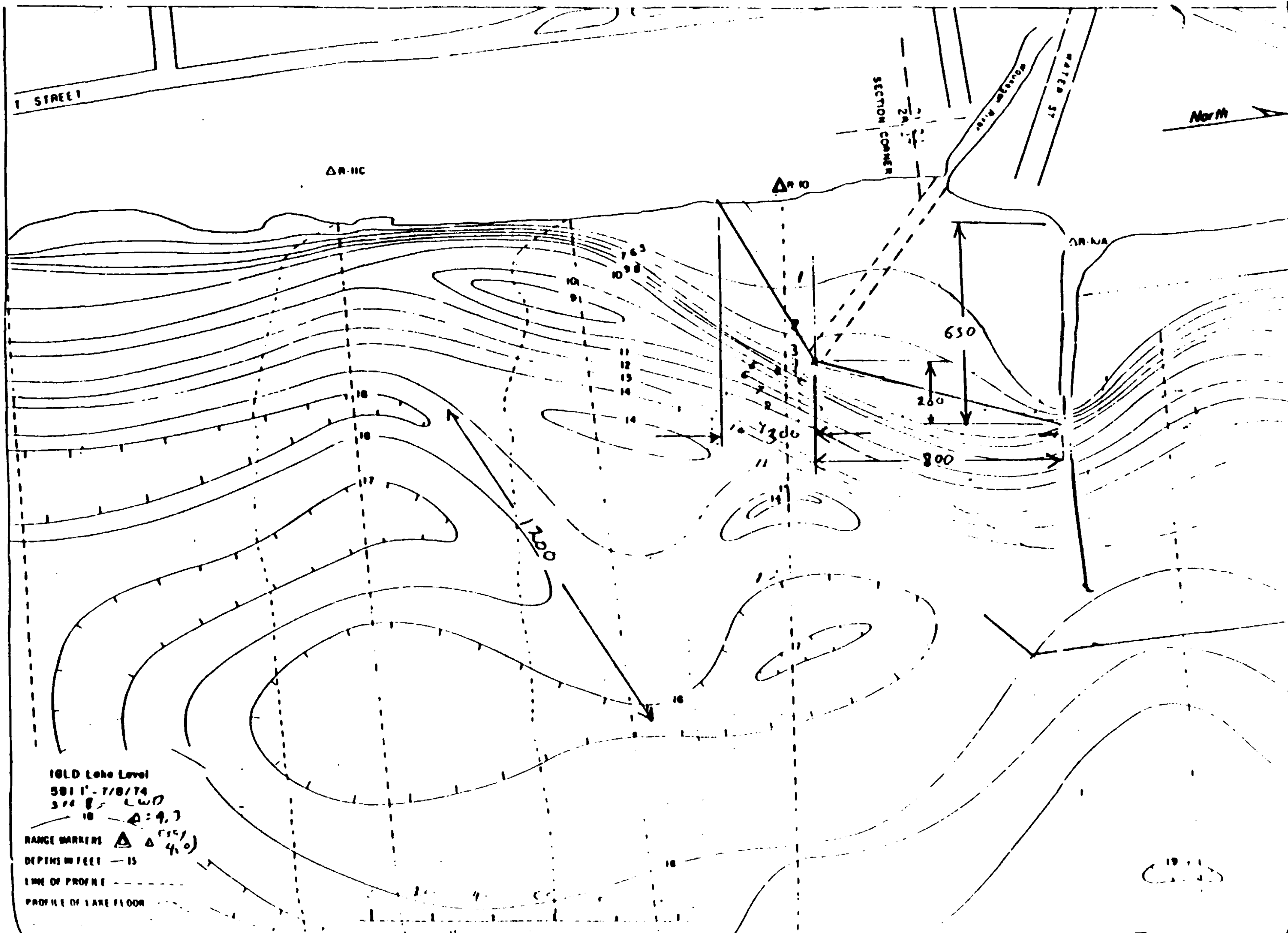
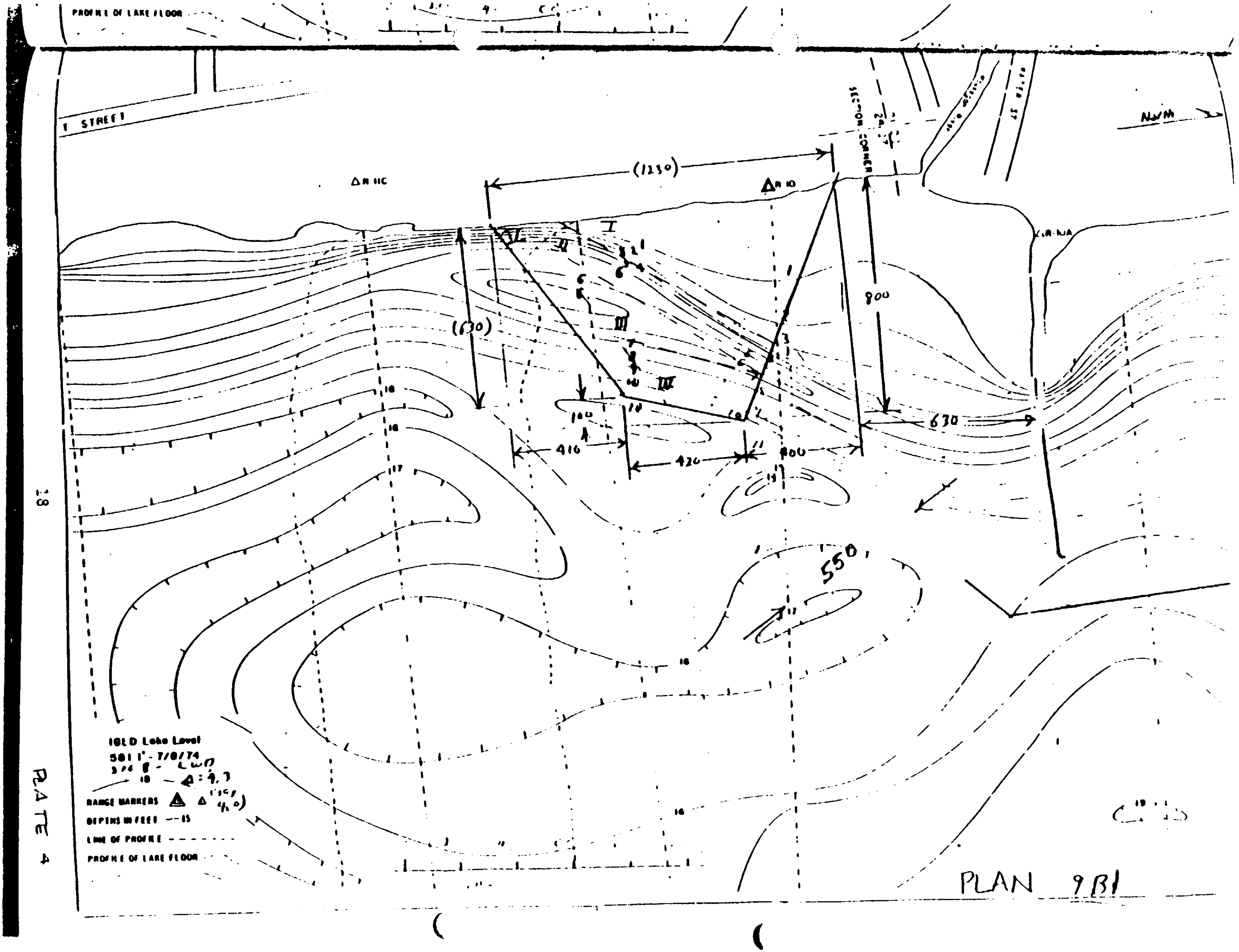

T STREET
SECTION CORNER
WATER ST
North
650
200
300
800
1200
IGLD Lake Level
RANGE MARKERS
DEPTHS IN FEET — 15
LINE OF PROFILE
PROFILE OF LAKE FLOOR

PLATE 3



PROFILE OF LAKE FLOOR
I STREET
SECTION CORNER
N/W
(1230)
R 11C
R 10
800
(630)
630
416
420
400
550
1610 Lake Level
PLATE 4
RANGE MARKERS
DEPTHS IN FEET
LINE OF PROFILE
PROFILE OF LAKE FLOOR
PLAN 9B1

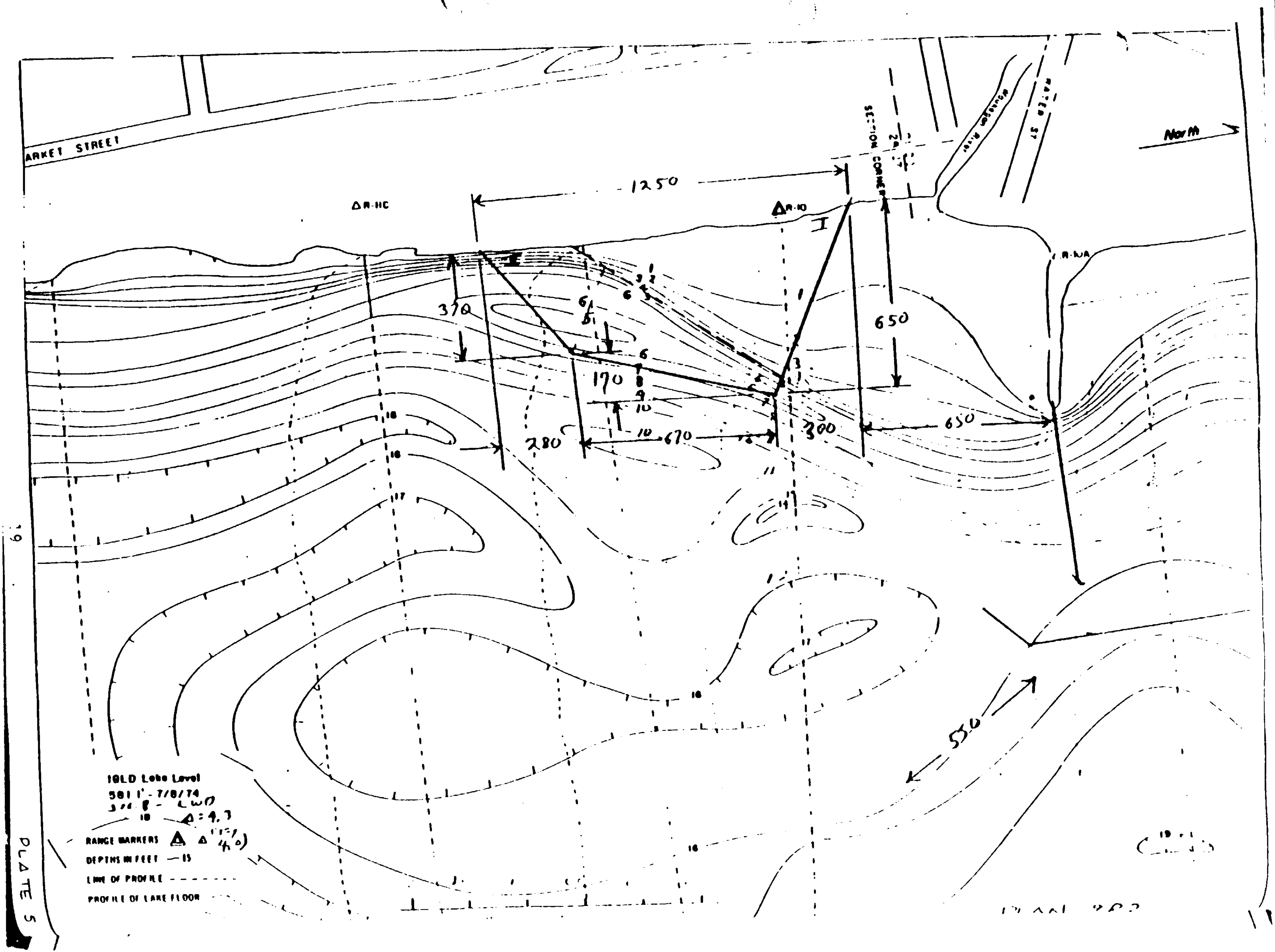
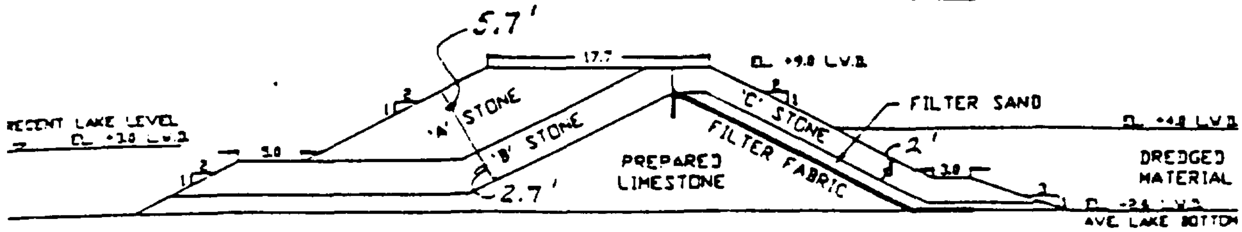


PLATE 5
MARKET STREET
North
WATER ST
Waukegan River
SECTION CORNER
ΔR-10
ΔR-11C
1250
650
650
370
170
280
670
300
550
IGLD Lake Level
581.1' - 7/8/74
RANGE MARKERS
DEPTHS IN FEET — 15
LINE OF PROFILE
PROFILE OF LAKE FLOOR

STONE SIZES

'A' STONE	1.8 - 4 TON
'B' STONE	200 - 800 LBS
'C' STONE	1 - 50 LBS

SITE 9A-1

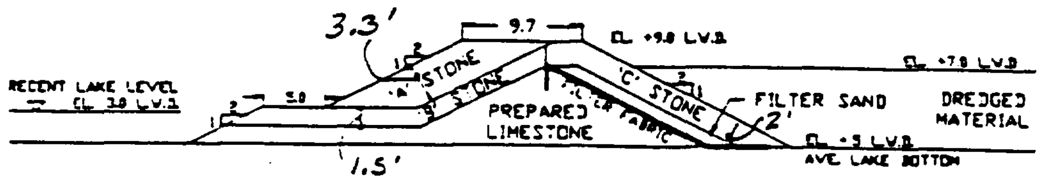


TYPICAL DIKE SECTION

STONE SIZES

'A' STONE	700 - 1500 LBS
'B' STONE	25 - 150 LBS
'C' STONE	1 - 50 LBS

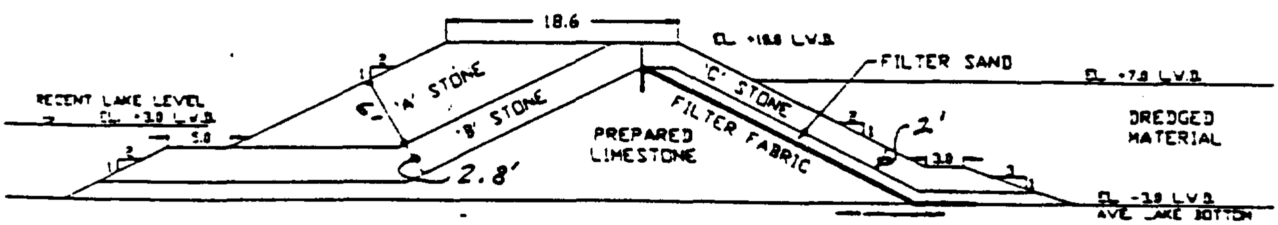
SITE 9A-2



STONE SIZES

'A' STONE	2 - 5 TON
'B' STONE	240 - 940 LBS
'C' STONE	1 - 50 LBS

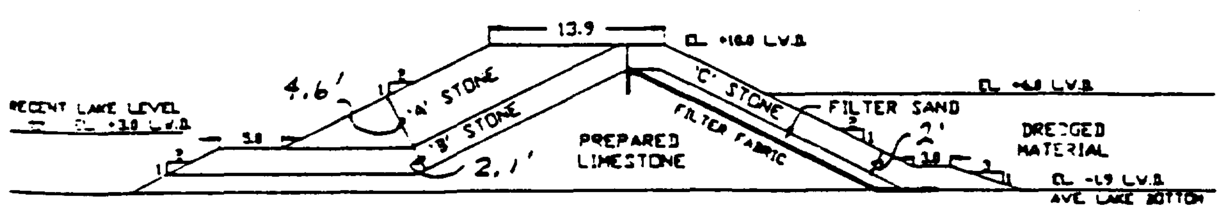
SITE 9B-1

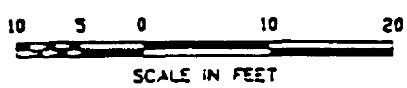


STONE SIZES

'A' STONE	1800 LBS - 2 TON
'B' STONE	100 - 400 LBS
'C' STONE	1 - 50 LBS

SITE 9B-2





VERTICAL DATUM IS I.G.L.D. (1955) L.W.D.

WAUKEGAN HARBOR
CONFINED DISPOSAL FACILITY
SITE SELECTION STUDY

CROSS SECTIONS

NCCED-H PLATE 6

WAUKEGAN HARBOR, ILLINOIS

CONFINED DREDGED MATERIAL
DISPOSAL FACILITY

SITE SELECTION STUDY
Supplement

Attachment 2
GEOTECHNICAL RECONNAISSANCE

ILLINOIS GEOLOGICAL SURVEY BORINGS IN THE VICINITY OF THE PROPOSED WAUKEGAN HARBOR CDF

James Knox - 1986

Abstract

Ten boreholes drilled in 1979 and ten boreholes drilled in 1976 in the vicinity of Waukegan Harbor provides information on three potential nearshore borrow areas for beach replenishment material. Thickness and volume of useable sediment, grain-size characteristics, and organic and metallic chemistry were obtained from the borehole samples. Average thicknesses for the three areas around Waukegan Harbor vary between 6 and 15 feet (1.8 and 4.6 m). Average grain sizes for the three areas around Waukegan Harbor are 3.06Ø (0.12 mm), 2.53Ø (0.17 mm), and 3.31Ø (0.10 mm). Most beaches sampled by the Illinois Division of Waterways indicate grain sizes larger than 2.0Ø (0.25 mm). Comparisons of the potential borrow material with that of the native beach indicates very little compatibility. The estimated amount of additional borrow material (overfill) needed to create a specific volume with a grain-size distribution equivalent to the native beach varies from a minimum of three to greater than 10 times the specific volume. Thus these nearshore borrow areas should not be considered as potential material for beach nourishment.

The proposed CDF at the mouth of the Waukegan River would be underlain by from 5 to 13 feet of fine sand. Underlaying these sands could be from 15 feet to 5 feet of Lake Michigan Formation loose silts and very soft to soft lacustrine clays, subject to extreme settlement or subsidence. This material would squeeze out from under a dike with a thin underlying sand blanket. Under the Lake Michigan sediments is a moderate hard to hard clay till that would be a very good dike foundation. The sand would allow seepage and the clay/silt permit settlement. This material may also be silty sands or gravel with no intervening soft or loose materials.

INTRODUCTION

A major portion of the Illinois shore of Lake Michigan shows the effects of erosion that resulted from the high lake levels of the 1970's and 1980's. Among these effects are diminishing beaches which line most of the shore. Some beach width changes are due to such short-term factors as yearly lake level fluctuations or storms. Of more importance, however, are the longer term lake level changes which operate in irregular cycles that range from 10 to 30 years in length. Beaches become narrow or disappear entirely during several successive years of high lake levels, but usually reestablish themselves during years of lower lake levels. For the most part, therefore, erosion and acceretion offset each other but if analyzed over several cycles, accretion generally does not entirely regain the ground lost to erosion. Therefore we can expect ongoing and continuing erosion of the present shoreline.

The absence of a beach or the presence of only a narrow beach may permit the full energy of the waves to impinge on the toe of a lake bluff and undercut the bluff face with subsequent slumping. After the slump has been disaggregated and dispersed by the waves and littoral current, the then denuded bluff is susceptible to even greater erosion. As the bluff retreats, so do the beaches. If sufficient beach width can be maintained to prevent wave attack on the toe of the bluff, the most important cause of bluff retreat will be stopped, whereupon erosion and accretion will be balanced.

Groins have come into widespread use for maintaining beaches along the Illinois shore. Longshore drift trapped by the groins provides a buffer between the lake and the bluff.

With an ever increasing number of groins capturing portions of the littoral drift and decreasing littoral drift moving south from Wisconsin into Illinois, many of the beaches are not sufficiently wide to prevent toe erosion of the bluff during higher lake levels or during severe storms. Under these circumstances, it it necessary not only to build groins but to artificially fill them with sediment of a suitable grain size to provide a stable beach of width sufficient to prevent toe erosion of the bluff.

As a temporary measure, unprotected eroding beaches can be widened by adding sediment; however, unless an economical method of recycling sediment from the downdrift end to the updrift end of the beach is also employed, the beach will continue to erode and must be renourished periodically. Toward this end, this report provides data on potential nearshore borrow areas that may contain sediment of a grain size suitable for use in replenishing the Illinois beaches.

PURPOSE AND SCOPE

During June, 1979, ten boreholes were drilled in the nearshore sands of Waukegan Harbor (figs. 1). Study of samples and logs of these boreholes yielded information on the grain size characteristics, thickness of sediments, areal extent of potential sand bodies, and amounts of organic and metallic pollutants. These data was utilized by the Illinois Department of Transportation, Division of Water Resources, to determine the suitability of sand for direct beach nourishment or for use in conjunction with other materials for maintaining beaches. These boreholes also provided supplemental information on depths to till or bedrock which will be available in correlating subsurface information with land records.

This study was supported by contractual funds from the Illinois Division of Water Resources. The Illinois State Geological Survey supervised the drilling program, recorded drilling data and collected samples for laboratory analyses. The drilling was performed under subcontract by Soil Testing Services, Inc. of Northbrook, Illinois. Barge and tug services were contracted to Falcon Marine Company of Waukegan, Illinois. During the period of drilling, ISGS personnel completed a hydrographic survey in the drilling area to obtain recent bottom topography which was necessary for computing sediment volumes.

Along with the data presented in this report, a summary of borehole information from the July, 1976 drilling around Waukegan Harbor (Norby and Collinson, 1977) is included as supplemental information.

METHODS

Field

Information provided by hydrographic mapping and previous drilling determined the selection of borehole locations that best satisfy the stated objectives. As the drilling progressed, the drill hole locations were adjusted according to data obtained. The truck-mounted Mobile drill rig (model B61) was secured to a barge to provide a floating drilling platform. The barge was positioned at each drilling site by tug boat. The position of each hole was determined by radar with triangulation checks of known shore locations. On station, the barge was anchored to the bottom by means of two thirty-foot (9.1 m) stiff-leg spuds. In the drilling operation, casing was set from the platform to the lake bottom. After each sample was taken, the casing was extended and driven into the bottom.

Samples were obtained by one of two methods. In the standard method, used for grain-size samples only, a 1 3/8 inches (3.5 cm) ID split-spoon sampler was attached to the end of a hollow stem drilling rod, lowered through the casing, and driven 18 inches (45.7 cm) into the bottom by either a 140-pound (63.6 kg) drop hammer or more generally by a 350-pound (158.9 kg) hammer which shortened the sampling time. The sampler was withdrawn from the hole and the sample was collected and recorded. The hole was drilled down through the last sampled interval and flushed. The sampler was then driven another 18 inches (45.7 cm) and the process repeated. In the second method which was similar to the first, a 5-foot (1.5 m stainless steel Shelby tube, 2.84 inches (7.22 cm) ID and 3.0 inches (7.62 cm) OD, was used as the sampler. The inside of the Shelby tube was washed with detergent and rinsed with acetone followed by nannograde hexane. The cleaned Shelby tube was used to obtain uncontaminated samples for organic and metallic chemical analyses as well as for grain size. Methods and equipment used in the 1976 drilling were described by Norby and Collinson (1977).

Laboratory

Standard grain-size analyses were performed with a series of 13 sieves (U.S. Standard Sieve Series) at half-phi intervals. Table 1 shows the grain-size classification used in this report. Tables 2 through 5 show a summary of the composite mean grain size, sorting, number of samples analyzed, percentage of sediment coarser than 2Ø (phi) and 2.5Ø (phi) as well as other physical data for each borehole.

The grain size values for each 1 1/2-foot (45.7 cm) split-spoon sample were mathmatically averaged to obtain a composite sample for the core. The gravel found at the contact between the sand and the underlying till was generally excluded from the composite, particularly in the deeper cores, as it would shift the mean and class percentages to the coarser end of the scale. In the 5-foot (1.5 m) cores which were more nearly complete, the samples were divided at close intervals (3-10 cm) in the upper portion of the first 5-foot (1.5 m) core to obtain more detailed chemical information for that interval. Samples for the remainder of the core and for second core, where taken were either divided at boundaries where grain-size changes were visibly discernable, or at regular intervals. For each core, samples were statistically weighted and then averaged to obtain a composite sample. The 5-foot cores for 1974 were sampled in a similar manner, although no samples were taken for chemical analysis.

Hydrography

Concurrent with the drilling program phase, bathymetric mapping was completed around Waukegan Harbor. The bathymetric data were gathered to assist in finding the greatest accumulation of sediment and any changes in bottom topography that had occurred since the 1974 mapping.

A comparison of 1974 maps with the 1980 map of the Waukegan area along with adjustments to compensate for lake level changes suggests a gain of 2 to 3 feet (0.6 to 0.9 m) of sediment immediately south of the Commonwealth Edison pier and in a few areas with depths of 5 feet (1.5 m) or less. However, much of the remainder of this reach between Waukegan Harbor and Commonwealth Edison shows a loss of between 1 to 4 feet (0.3 to 1.2 m) of sediment since 1974. Examination of an unpublished 1975 bathymetric map of this area on file at the Survey shows that most of this loss occurred between the summers of 1974 and 1975.

South of Waukegan Harbor, 2 to 3 feet (0.6 to 0.9 m) of sediment has accumulated in depths of 10 feet (3.0 m) or less immediately south of the south jetty. In depths of 12 feet (3.7 m) or greater, no differences greater than about one foot (0.3 m) could be found in comparisons with 1974 maps. The small differences may be real or they may be due to small inaccuracies in mapping or to different profiling patterns employed for the two maps.

The change in bottom topography or lack of change is not surprising. The lake levels during the 1974 survey (581.1 feet or 177.0 meters IGLD) and during the 1979 survey (580.0 feet or 176.7 meters) are only slightly different and for intervening years, the lake level has not varied substantially. At the time of the 1974 survey, the lake level has about reached its peak after a dramatic rise which began in the mid-1960s. The nearshore lake bottom, for the most part, had apparently adjusted to the lake levels rise by 1974 or 1975, as very little change has occurred since then, with the exception of an area north of Waukegan Harbor which had adjusted by 1975. No surveys have been made since 1975 in this area, therefore variations in the bottom topography may have occurred in this time interval.

Table 1. Wentworth grain size classification and sieves used in grain size analysis

Size Class	Class limits		U.S. Standard Sieves used for analysis
	mm	phi	
Boulder			
	256.00	-8.0	
Cobble			
	64.00	-6.0	
Pebble			
	4.00	-2.0	5
Granule	2.83	-1.5	7
	2.00	-1.0	10
Very coarse sand	1.41	-0.5	14
	1.00	0	18
Coarse sand	0.71	0.5	25
	0.50	1.0	35
Medium sand	0.35	1.5	45
	0.25	2.0	60
Fine sand	0.177	2.5	80
	0.125	3.0	120
Very fine sand	0.088	3.5	170
	0.062	4.0	230
Silt			
	0.0039	8.0	
Clay			

TABLE 1—A summary of borehole information and grain-size data obtained in the June, 1979 drilling south of Waukegan Harbor

Lake Mich. No.	Borehole (Fig. 1)	Water depth (in feet)	Thickness of sand (in feet)	Subbottom Encountered	Composite grain size* mean (ø)	Composite grain size* sorting (ø)	N	Composite grain size,* % larger than 2ø (0.25mm)	Composite grain size,* % larger than 2.5ø (0.18mm)
1162	WH-1	18.5	8.0	Till	2.87	0.64	5	8.1	22.0
1163	WH-2	16.5	8.4	Till	2.89	0.79	11	7.5	23.2
1164	WH-3	16.5	9.0	Till	3.57	1.11	6	7.5	21.0
1165	WH-4	19.5	7.25	Till	2.61	0.41	9	7.4	39.0
1166	WH-5	18.0	21.0	Rock?	3.14	0.98	13	12.5	31.9
1167	WH-6	25.0	0.75	Till	3.49	0.79	1	3.2	8.5
1168	WH-7***	18.0	9.0 and 9.0 gravel	Rock	2.96	0.52	4**	2.6	12.0
1169	WH-8	17.5	3.8	Rock?	3.55	0.99	3	3.9	17.9
1170	WH-9	15.0	7.4	Rock?	2.88	1.18	5	13.7	30.6
1171	WH-10	15.0	5.75	Till	2.84	0.70	4	8.5	25.1

*Composite grain size obtained by averaging samples for the core and does not include the few inches of gravel immediately above the subbottom.
**Only upper 4 samples analysed.
***This borehole is apparently in a pocket caused by glacial plucking of bedrock; the lower 9 feet are coarse gravel and small cobbles—all angular and primarily of dolomitic limestone.

TABLE 3—A summary of borehole information and grain size data obtained in the July, 1976 drilling around Waukegan Harbor

Lake Mich. No.	Borehole (Fig. 1)	Water depth (in feet)	Thickness of sand (in feet)	Subbottom encountered	Composite grain size* mean (ø)	Composite grain size* sorting (ø)	N	Composite grain size,* % larger than 2ø (0.25mm)	Composite grain size,* % larger than 2.5ø (0.18mm)
1135	W-1	17.5	8.0	Till	2.83	1.18	7	21.2	34.4
1136	W-1B**	17.8	6.0 and 11.0 gravel	?	-0.05	NC	16	66.1	74.7
1137	W-2	14.8	8.0	Till?	3.05	1.11	14	15.6	45.8
1138	W-3	24.8	8.5	Till?	2.54	1.07	10	9.5	20.7
1139	W-4	27.6	6.0	Till?	2.95	0.90	8	11.6	23.2
1140	W-5	28.8	4.5	Till	2.10	1.96	4	22.7	31.1
1141	W-6	11.7	22.2	Till	3.15	0.81	16	6.7	12.2
1142	W-7	18.8	15.2	Till	3.38	0.42	10	3.7	5.7
1143	W-8	26.0	11.0	Till	3.50	0.45	6	2.8	5.2
1144	W-9	22.5	15.75	Till	3.23	0.59	10	6.2	9.7
1145	W-10	14.3	17.7	Till?	3.15	0.57	10	5.2	10.2

*Average composite grain size consists of weighted samples and includes all sediment above the subbottom. Therefore the presence of coarse sand and gravel just above the subbottom cause the composite grain size to appear slightly coarser than if only the sand samples were analysed.
**This borehole is apparently in a pocket caused by glacial plucking of bedrock; the lower 11 feet are coarse gravel and small cobbles—all angular and primarily of dolomitic limestone.

Table 5. Mean grain size of prenourished beaches and other beaches along the Illinois shore in 1946 and 1950 (from Illinois Department of Public Works and Buildings, Division of Waterways, 1952)

Municipality	Location	Mean grain size (mm) 1946 Water's edge	1950 Water's edge	1950 Mid-beach
Winthrop Harbor	State line	0.30	0.40	0.26
Camp Logan	2500' N. of 17th St.	0.50	1.50	0.26
Zion	Ariel Ave.	0.33	2.50	0.25
Ill. Bch. St. Pk.	Beach Rd.	1.00	1.50	1.36
Ill. Bch. St. Pres.	7000' N. of Waukegan boundary	0.68	0.42	0.27
Waukegan	Commonwealth Edison Pier	0.95	0.22	1.88
	500' N. of Seahorse Dr.	0.20	0.15	0.16
	Southern Harbor jetty	0.18	0.16	0.18
	Waukegan River	0.30	1.00	0.26
North Chicago	U.S. Steel	-	1.00	0.50
Great Lakes	Northern Harbor jetty	0.19	0.28	0.20
Lake Bluff	McCormick-Blair property	0.30	6.17	-
	500' N. of Center Ave.	0.32	0.50	0.27
Lake Forest	Deerpath Ave.	0.50	0.38	0.31
	2000' N. of Westleigh Rd.	-	0.30	0.30
Fort Sheridan	700' S. of Lake Forest boundary	>10.00	0.50	0.22
Highland Park	1500' S. of Fort Sheridan boundary	2.40	0.24	0.25
	Old Sewage Plant	2.00	1.00	0.33
	Clavey Ave.	0.30	0.23	0.21
Winnetka	3500' N. of Tower Rd.	>10.00	-	-
	Winnetka Ave.	0.23	-	-
Wilmette	10th St.	0.56	-	-
Chicago	Loyala Park	0.20	-	-
	Foster Ave.	0.28	-	-

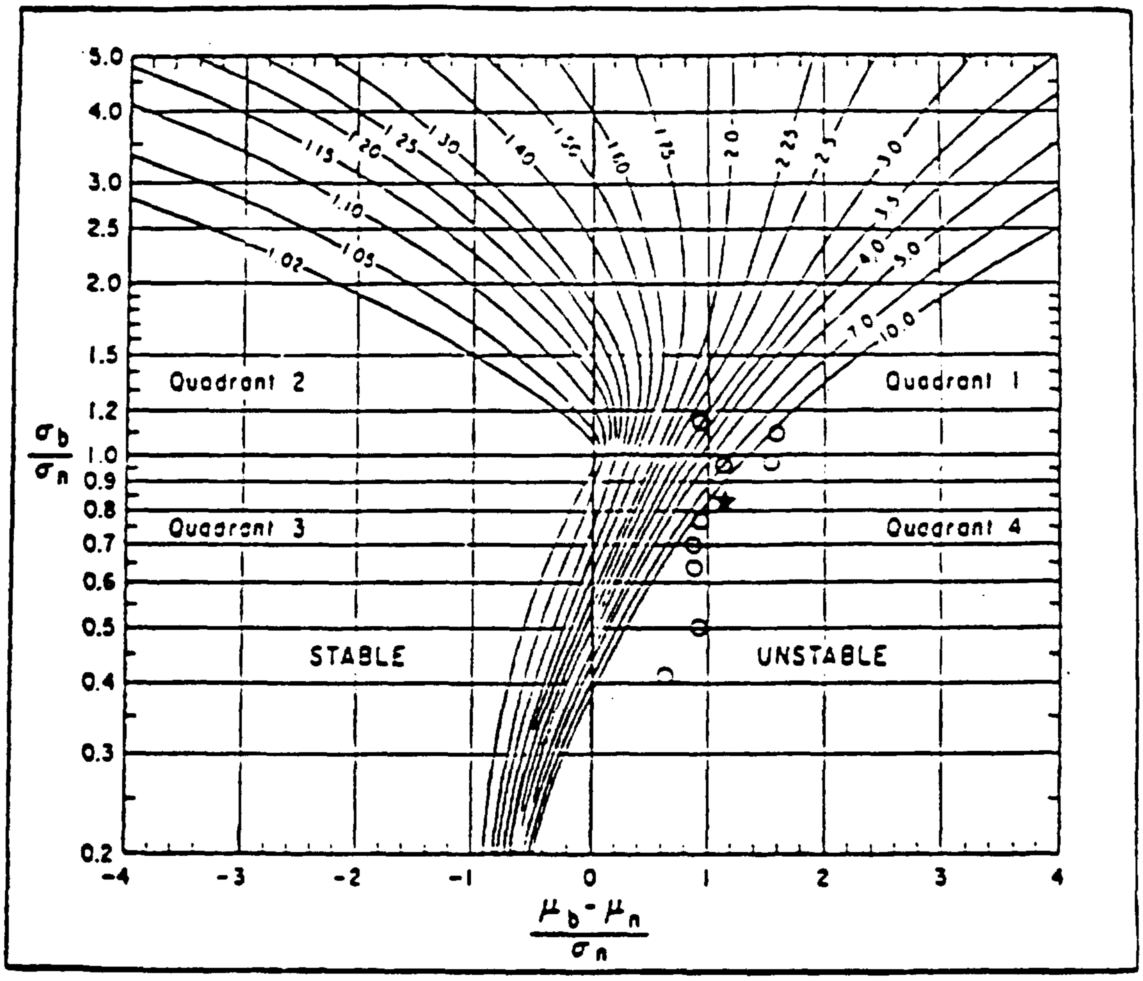


Fig.4 - Isolines of the adjusted SPM fill factor versus phi mean difference and phi sorting ratio (Hobson, 1977, as modified from James, 1975). The star indicates a conservative overfill factor for sediment from Area A based on the nine boreholes drilled within the area in 1979. The overfill factor applies to use for replenishment of Lake Michigan beaches in Illinois. Values used are μ_b = 3.08, μ_n = 2.0, σ_b = 0.8 and σ_n = 1.0. The open circles represent separate overfill factors for each of the nine boreholes (table 2 has values for μ_b and σ_b).

BOREHOLE RESULTS

Sediment Distribution around Waukegan Harbor

The drilling data and fathometer survey indicate three areas (Area A, B, and C) of moderate sediment accumulation around Waukegan Harbor (fig. 1). Area A, south of the south harbor jetty, is approximately 250 acres (1.0 km^2). Here nine boreholes from the 1979 drilling (table 2) and three holes from 1976 (table 4) indicate an average thickness of 10.1 feet (3.0? m) of sediment. As the boreholes do not represent equal areas and the subbottom has an irregular topography, some adjustment in this average thickness needs to be made. Seven of the boreholes indicate consistent thicknesses between 7.25 and 9.0 feet (2.21 and 2.74 m). Three boreholes show a typically high thicknesses for the area. Two of the three holes have an upper unit of sand and a lower unit that ranges between a very poorly sorted (= 2 to 4) and an extremely poorly sorted (>4) sediment consisting primarily of angular dolomite gravel. Sigma ( ) is a sorting coefficient or the standard deviation from the mean grain size. The gravel was possibly derived from glacial abrasion of dolomite bedrock highs, some of which are only a few hundred to a few thousand feet to the north and east. The gravel unit lies below the elevation of the top of the till subbottom and it may be in a pocket scoured out by the glaciers or in a channel of the ancestral Waukegan River. An adjustment by subtracting the gravel unit in the three atypical boreholes results in sand thicknesses of 6, 9, and 9 feet (1.8, 2.7, and 2.7 m). The adjusted average thickness for the boreholes is now 7.4 feet (2.25 m) which is considered typical for the area. Another 1 foot (0.3 m) of sediment is added to this average to allow for pockets or channels of sediment. Area A contains a volume between 3.0 and 3.5 x 10^6 cubic yards (2.3 and 2.7 x 10^6 m^3). The average grain size for the sediment in 11 of the 12 boreholes is 3.06ϕ (0.12 mm). Boreholes W-13 is not used in this average as it contains a lower unit of angular dolomite gravel and cobbles. This average is not weighted between boreholes but it is a useful guide to the general grain size for the volume represented.

Area B, east of the Waukegan Harbor mouth contains approximately 90 acres (0.36 km^2). The bottom and subbottom configuration is significantly irregular, therefore the 6.3 foot (1.9 m) average thickness for the three holes drilled there in 1976 is only approximate. Using the average thickness a sediment volume of approximately 0.9 x 10^6 cubic yards (0.69 x 10^6 m^3) is calculated. The grain size for the three holes, which varies greatly, averages 2.53ϕ (0.18 mm).

Area C contains about 450 acres (1.82 km^2) and lies between Waukegan Harbor's north jetty and the Commonwealth Edison pier. The average sediment thickness is around 15 feet (4.6 m) based on 4 boreholes as well as bottom and subbottom profiles. Approximately 11 x 10^6 cubic yards (8.4 x 10^6 m^3) of sediment underlies Area C. The grain-size average for the 4 holes drilled here in 1976 is 3.31ϕ (0.10 mm). The grain size, as in many areas, becomes coarser closere to shore as indicated by hole W-6 (3.15ϕ or 0.11 mm). The subbottom is generally till but bedrock is believed to be represented in several borehole.

Organic and metallic chemical analyses are being performed only on borehole WH-2 and WH-4 in Area A. Final results of the analyses are not yet available but preliminary results do not indicate any abnormalities.

GRAIN-SIZE CHARACTERISTICS OF BEACHES ALONG THE ILLINOIS SHORE

A comprehensive statistical study of the grain size of beach material along the Illinois shore is beyond the scope of this study, even though the report would benefit from such information. Knowledge of the approximate grain size and sorting coefficient, however, is critical in determining the capacity of a given grain size to remain stable on an Illinois beach under anticipated conditions.

The grain-size distribution on a Lake Michigan beach will vary seasonally or even daily, due to storms, lake level changes, wave climate, etc., but these changes are generally not as extreme as those that occur on oceanic beaches. Grain-size variations also exist along the beach depending on protection of the beach from waves, angle of incoming waves, nearshore slope, etc. They also exist across the beach with the most extreme variations occurring near the swash zone. Thus one or two samples taken on a beach compared with samples taken at other times and from other beaches are not sufficient to classify beaches into categories with any confidence unless the grain sizes tend to be consistent within some range. The Illinois State Geological Survey has collected samples at various times under various conditions along the Illinois shore with most samples concentrated in the Illinois Beach State Park. Three different beach profiles were shown with 5 to 10 samples per profile. The sample with the finest grain size had a median diameter of about 2.0ϕ (0.25 mm). It was collected from the swale behind a washover bar.

In 1952, a report was published by the Illinois Department of Public Works and Buildings, Division of Waterways which shows grain-size data for the years 1946 and 1950 at numerous locations along the entire Illinois shore (table 5). The 1946 data are only for the water's edge (probably swash zone) and the 1950 data for the water's edge and mid-beach. The samples were probably collected in a consistent manner over a relatively short time interval for each of the two years, thereby providing a range of values for comparison with the nearshore sediment values. Table 6 shows the smallest grain-size diameter to be 2.75ϕ (0.15 mm) for samples taken in 1950 from the north side of the northern Waukegan Harbor jetty. Only 16 values of the 62 grain-size values for 1946 and 1950 are finer than 2.0ϕ (0.25 mm). The grain sizes for the mid-beach samples are more closely grouped and give a good indication of what would be stable on the inactive beach. The lowest value is 2.65ϕ (0.16 mm) but 14 out of 19 values occur between 2.35 (0.20 mm) and 1.6ϕ (0.33 mm) with an average of 1.99ϕ (0.256 mm) for these 14 values. These data suggest that material of an average grain size of 2.0ϕ (0.25 mm) may be stable on the inactive beach but that a larger grain size is required for stability on the active beach.

Berg (1980), in a companion report, has compiled detailed information on the grain size specifications of nourishment material emplaced on several public beaches along the Illinois shore. Berg reported that the North Shore Sanitary District emplaced a pea gravel material (approximately -3.0Ø or 8 mm) along the shore in both Lake Bluff and Highland Park at several times since 1973. This material has been very stable over the short time interval during which higher than normal lake levels have prevailed. In 1978, material with a mean grain size of -1.31Ø (2.5 mm), was emplaced along part of the Fort Sheridan shore as part of a Corps of Engineers bluff erosion control program. This project area, however, has not had sufficient time for a reliable test. The city of Evanston nourished its beaches with material which required a specified mean grain size of at least 1.03Ø or 0.484 mm (U.S. House of Representatives, 1965). In the same report, sand from the lake bottom at Wilmette Harbor and at Jackson Park, which had respective grain sizes of 2.18Ø (0.221 mm) and 2.12Ø (0.230 mm), was considered unsuitable for nourishment of Evanston beaches.

Berg (1980) briefly commented on criteria used by others in renourishing depleted beaches and their results. The conclusion is that renourishment material should be similar to the native beach in its grain size distribution or if possible slightly coarser material should be utilized. On some beaches, it may be possible to use a sediment of a finer grain size than the native material provided the native material is relatively coarse and that the beach is stable. In these instances, the beach and nearshore profiles readjust to the finer sediment by forming a more gentle slope. One such example might be an unprotected beach which has gained some wave protection either naturally or artificially. Stable beaches, however, are seldom nourished because they are stable. Beaches are generally renourished because they are unstable. Hobson (1977) has indicated in cases where erosion is prevalent, that the grain size of the native or present material is not coarse enough to provide stability and that any renourishment material should be somewhat coarser than the native sediment.

What is the minimum grain size that can be used in renourishment of beaches? This depends greatly on the particular situation, but Bascom (1951, p. 869) after an intensive study of about 40 beaches on the West Coast, indicated that "wave action, even in the most protected locations, seems to remove sand smaller than 0.17 mm from the beach face." In tables 2 and 4, the percentage of sediment coarser than 2.5Ø (0.18 mm), but not including boreholes with gravel pockets, varies between 5.2 and 45.8% in the boreholes around Waukegan Harbor. The percentage of sediment coarser than 2.0Ø (0.25 mm), which the city of Evanston would probably consider too fine to be used on their beaches, varies from 2.6% to 22.7% for those same boreholes. Sediment of the 2.0Ø and larger size would most likely be incorporated into the native beach material, but this grain size forms such a small portion of the borrow area, that larger overfill factors would result. (An overfill factor is the additional amount of material needed from a borrow area in order to produce a specified volume of sediment that is equivalent to the native material in grain size distribution.) Also, some of the 2Ø size fraction might be lost with the main mass of finer sediment during the large winnowing action.

If sediment from Area A (the coarsest main area) was utilized as a borrow area and if sediment coarser than 2.5φ was found to be stable on specific beaches, then about 28% (averaging 11 boreholes in Area A) of the sediment is coarser than 2.5φ and approximately 3.5 times the specified volume of sediment is required to produce a volume with the minimum grain size of 2.5φ. If the minimum grain size is deemed to be 2.0φ, then about 10% of the sediment is coarser than 2.0φ and approximately 10 times the specified volume is required.

Several sedimentologists (Krumbein and James, 1965; Dean, 1974; James, 1974, 1975) have devised mathematical models and formulas to use in estimating compatibility of borrow and native sediments along with overfill factors when these two sediments are not totally compatible. Hobson (1977) has compared these models and the model which seemed to take most parameters into consideration was the adjusted SPM method of James (1975). This method assumes that losses to the fill material will be from all sizes finer than the critical size but that material coarser than the critical size willb e retained. Estimates of this overfill ratio can be obtained by using the graph in figure 4. The information required to use the graph are the phi mean grain size and phi sorting coefficient (standard deviation) for both native and borrow composites. The mean grain size ($_b$) for borrow Area A averaged 3.08φ (0.12 mm) for the 9 boreholes of 1979 and the average of the sorting coefficient ($_b$) is 0.81. The sorting coefficient is probably a little high as it should be determined from a composite mixed sample rather than from arithmetic averaging of several composite samples. For the native sediments some assumptions will need to be made in order to determine values for $_n$ and $_n$. From an analysis of Table 6 given earlier, a minimum average $_n$ is probably greater than 2.0φ (0.25 mm), but we will use $_n$ = 2.0φ in this case. Sorting coefficients of the beach samples were not given in the report by the Illinois Division of Waterways (1952). However, beach sediment is normally moderately sorted (= 0.7 to 1.0) to poorly sorted (= 1.0 to 2.0). Values lower than 0.7 and higher than 2.0 also occur. Bascom (1951) noted that sorting coefficients of beach face sand were usually between 1.1 and 1.3. Unpublished data from beach samples in Illinois Beach State Park also indicate is often greater than 1.0, but in this hypothetical case, $_n$ is set at 1.0. The phi mean difference and phi sorting ratio are calculated from the four values given and the intersection of the two ratios are shown by the star in figure 4. This point lies within the unstable fill area but close to the fill factor isoline of 10.0. In addition to the phi mean and phi sorting for Area A as a whole, values for each individual borehole were calculated and marked on the graph in figure 4. Individual boreholes again fall within the unstable fill area although four boreholes fall near overfill factor isolines of 3, 7, and 10. If the mean grain size difference of the borrow and native sediment increases or the sorting coefficient of the borrow material is lower or the sorting coefficient of the native beach is higher, then the plot of the points will be farther away from the overfill isolines.

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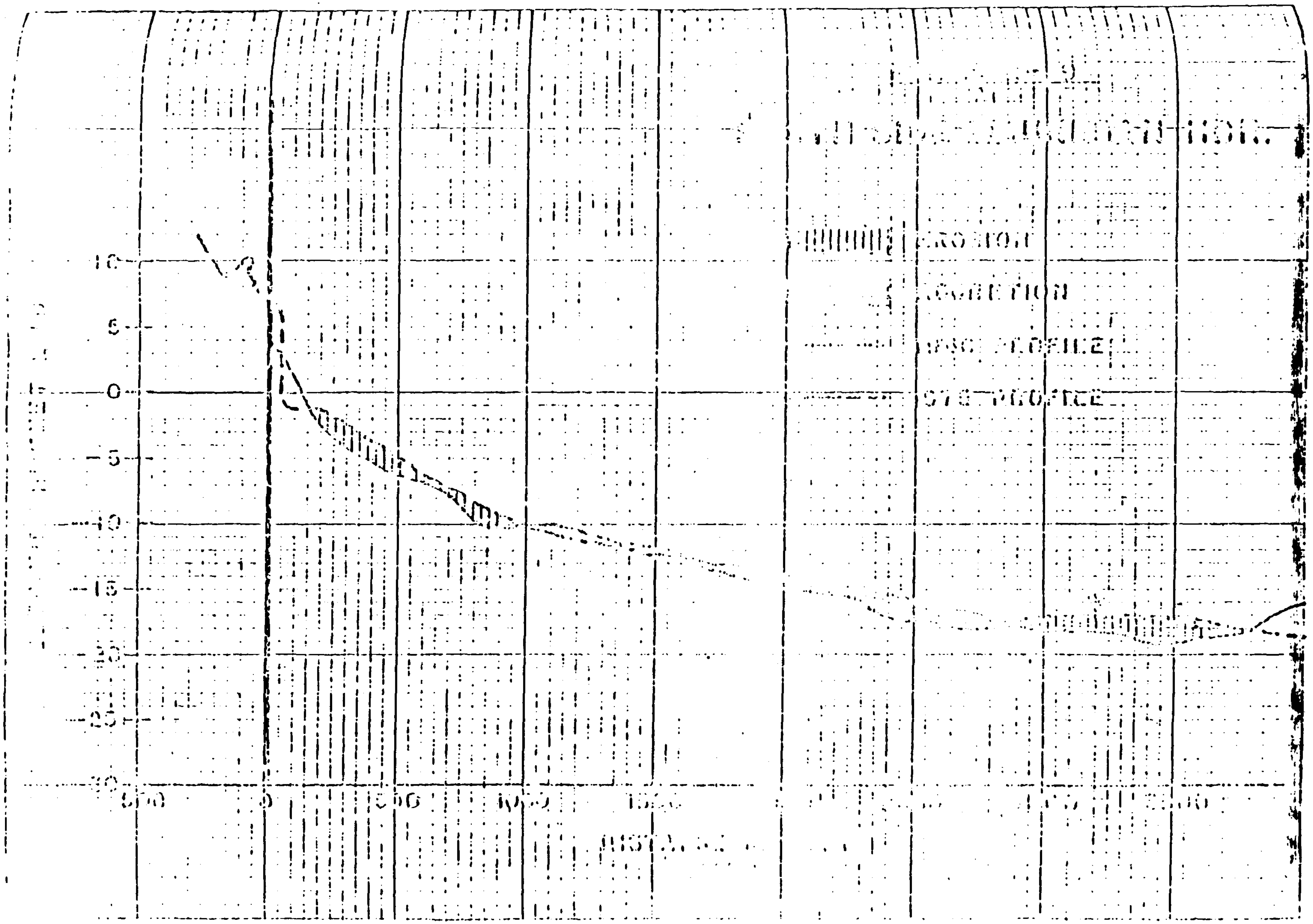
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10
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1000
1500

SEDIMENT DISTRIBUTION AROUND WAUKEGAN HARBOR

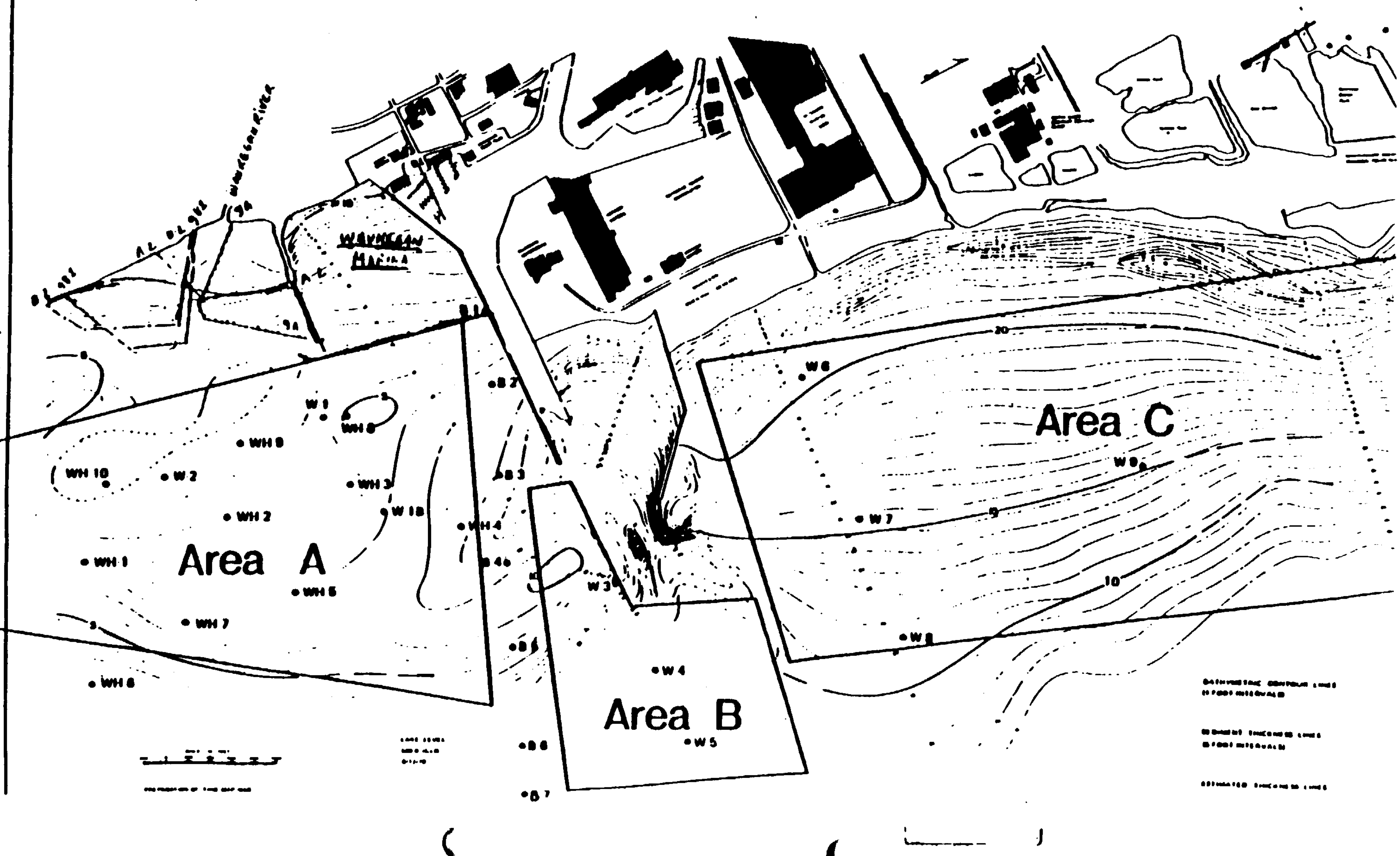
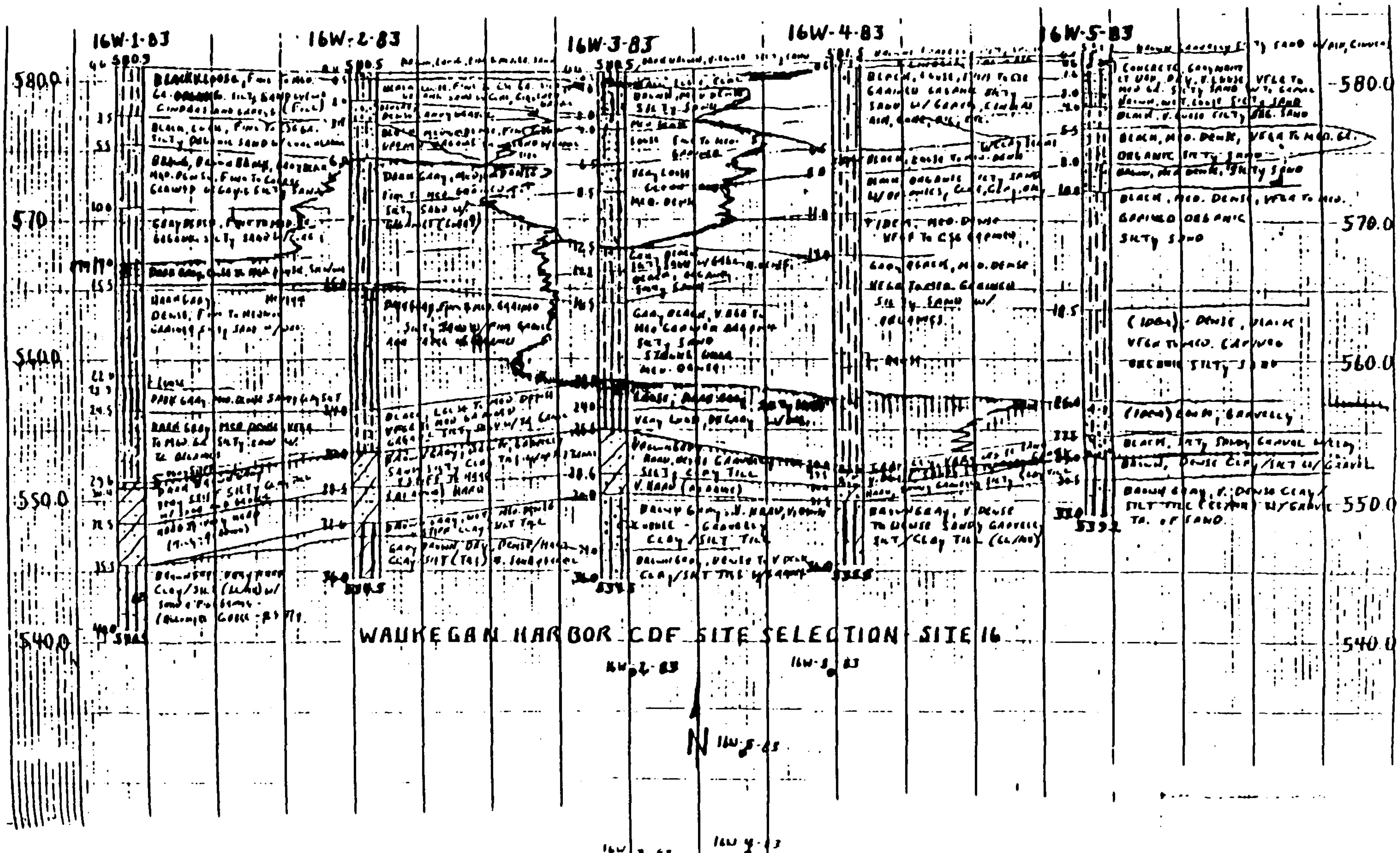


Figure 1. Sediment Distribution around Waukegan Harbor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WAUKEGAN HARBOR CDF SITE SELECTION SITE 16
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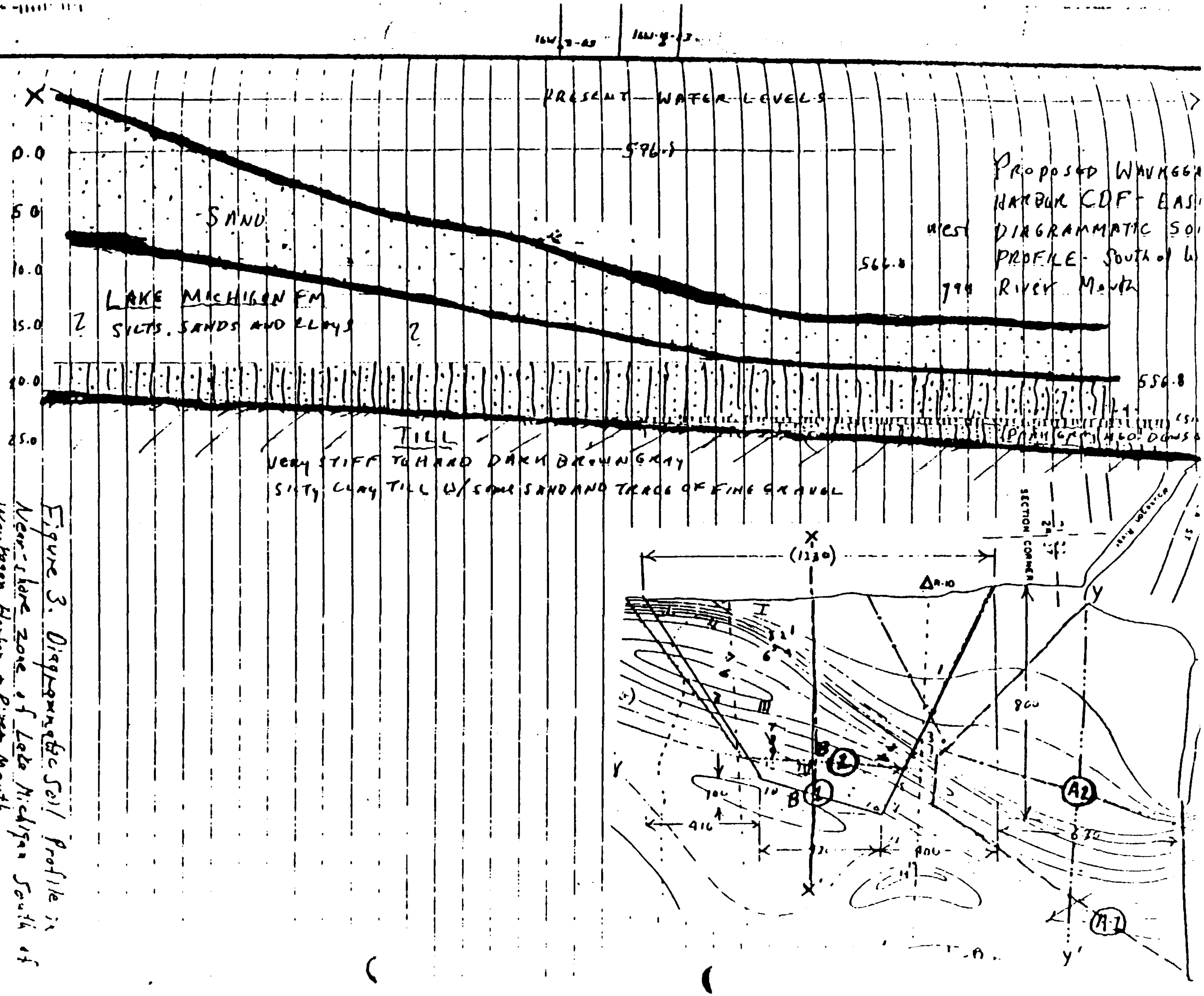

Figure 3. Diagrammatic Soil Profile in Near-shore zone of Lake Michigan South of Waukegan Harbor + River Mouth

WAUKEGAN HARBOR, ILLINOIS

CONFINED DREDGED MATERIAL
DISPOSAL FACILITY

SITE SELECTION STUDY
Supplement

Attachment 3

COST ESTIMATES

WAUKEGAN CDF SITE SELECTION STUDY SUPPLEMENT

SHEET 1 OF 1

PROJECT SITE: 9A-1

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	STONE DIKE				
a	EXCAVATION	59,000	CY	6.00	$ 354,000
b	A - STONE 1.9 TON - 4.00 TON	11,000	TON	42.00	462,000
c	B - STONE 200 LB - 800 LB	12,000	TON	38.00	456,000
d	C - STONE 1 LB - 50 LB	8,600	TON	20.00	172,000
e	PREPARED LIME STONE	26,000	TON	12.00	312,000
f	FILTER SAND	4,900	CY	10.00	49,000
g	FILTER FABRIC	9,000	SY	5.00	45,000
2	CAP				
a	SAND LAYER	24,000	CY	8.00	192,000
b	CLAY LAYER	48,000	CY	10.00	480,000
c	GRAVEL 6"	72,000	SY	4.00	288,000
d	PAVEMENT	72,000	SY	6.00	432,000
	TOTAL 1+2				3,242,000
	CONTINGENCIES	25%			810,000
	CONSTRUCTION COST				4,052,000
	E & D	10%			405,000
	S & A	6%			243,000
	TOTAL				$ 4,700,000
3	DREDGING AND PLACING IN CDF INCL. CONTINGENCIES, E&D AND S&A	218,000	CY	11.60	2,529,000
	TOTAL				$ 7,229,000

ENG FORM 1738 APR 67 SUPERSEDES ENG FORM 1738, 1 APR 54, WHICH IS OBSOLETE.

WAUKEGAN CDF SITE SELECTION STUDY SUPPLEMENT

PROJECT SITE: 9A-2

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	STONE DIKE				
a	EXCAVATION	52.000	CY	6.00	$ 312.000
b	A - STONE 700 LB - 1500 LB	3.700	TON	42.00	155.000
c	B - STONE 25 LB - 150 LB	3.400	TON	38.00	129.000
d	C - STONE 1 LB - 50 LB	6.900	TON	20.00	138.000
e	PREPARED LIME STONE	13.000	TON	12.00	156.000
f	FILTER SAND	1,200	CY	10.00	12.000
g	FILTER FABRIC	5.600	SY	5.00	28.000
2	CAP				
a	SAND LAYER	23.500	CY	9.00	199.000
b	CLAY LAYER	47.000	CY	10.00	470.000
c	GRAVEL 6"	71.000	SY	4.00	254.000
d	PAVEMENT	71.000	SY	6.00	426.000
3	EARTH DIKE & CULVERTS				
a	96" ROUND MULTIPLE CULVERT	4060	LF	425.00	1.725.000
b	DIKE FOR MULTIPLE CULVERT	LS	JOB	-	72.000
	TOTAL 1 + 2 + 3				4.095.000
	CONTINGENCIES	25%			1.024.000
	CONSTRUCTION COST				5.119.000
	E & D	10%			512.000
	S & A	6%			307.000
	TOTAL				$ 5.939.000
4	DREDGING AND PLACING IN CDF INCL. CONTINGENCIES, E & D AND S&A	219,000	CY	11.60	2.5[illegible]
	TOTAL				$ 8.467.0[illegible]

ENG FORM APR 67 1738 SUPERSEDES ENG FORM 1738, 1 APR 54, WHICH IS OBSOLETE.

WAUKEGAN CDF SITE SELECTION STUDY SUPPLEMENT

SHEET 1 OF 1

PROJECT SITE: 93-1

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	STONE DIKE				
a	EXCAVATION	11,000	CY	6.00	$ 66,000
b	A - STONE 2 TON - 5 TON	14,000	TON	48.00	672,000
c	B - STONE 240 LB - 2400 LB	15,000	TON	38.00	570,000
d	C - STONE 1 LB - 50 LB.	7,000	TON	20.00	140,000
e	PREPARED LIME STONE	34,000	TON	12.00	408,000
f	FILTER SAND	3,000	CY	10.00	30,000
g	FILTER FABRIC	7,400	SY	5.00	37,000
2	CAP				
a	SAND LAYER	21,000	CY	8.00	168,000
b	CLAY LAYER	42,000	CY	10.00	420,000
c	GRAVEL 6"	62,000	SY	4.00	248,000
d	PAVEMENT	62,000	SY	6.00	372,000
	TOTAL 1+2				3,131,000
	CONTINGENCIES	25%			783,000
	CONSTRUCTION COST				3,914,000
	E & D	10%			391,000
	S & A	6%			235,000
	TOTAL				$ 4,540,000
3	DREDGING AND PLACING IN CDF Incl. Contingencies, E&D & S&A	218,000	CY	11.60	2,529,000
	TOTAL				$ 7,069,000

WAUKEGAN CDF SITE SELECTION STUDY SUPPLEMENT

SHEET 1 OF 1

PROJECT SITE: 9B-2

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	STONE DIKE				$
a	EXCAVATION	77,000	CY	6.00	462,000
b	A - STONE 1800 LB - 2 TON	9,000	TON	42.00	378,000
c	B - STONE 100 LB - 400 LB	9,500	TON	35.00	333,000
d	C - STONE 1 LB - 50 LB.	4,000	TON	20.00	80,000
e	PREPARED LIME STONE	24,000	TON	12.00	288,000
f	FILTER SAND	6,000	CY	10.00	60,000
g	FILTER FABRIC	6,000	SY	5.00	30,000
2	CAP				
a	SAND LAYER	17,000	CY	8.00	136,000
b	CLAY LAYER	33,000	CY	10.00	330,000
c	GRAVEL 6"	50,000	SY	4.00	200,000
d	PAVEMENT	50,000	SY	6.00	300,000
	TOTAL 1+2				2,597,0[illegible]
	CONTINGENCIES	25%			647,0[illegible]
	CONSTRUCTION COST				3,234,[illegible]
	E & D	10%			324,[illegible]
	S & A	6%			194,[illegible]
	TOTAL				$ 3,75[illegible]
3	DREDGING AND PLACING IN CDF INCL. CONTINGENCIES, E&D AND S&A	216,000	CY	11.60	2,50[illegible]
	TOTAL				$ 6,281[illegible]

WAUKEGAN HARBOR, ILLINOIS

CONFINED DREDGED MATERIAL
DISPOSAL FACILITY

SITE SELECTION STUDY
Supplement

Attachment 4

PRELIMINARY ENVIRONMENTAL
ASSESSMENT

PRELIMINARY ENVIRONMENTAL ASSESSMENT OF SITE 9, WAUKEGAN HARBOR, ILLINOIS MAINTENANCE DREDGING AND CONFINED DISPOSAL FACILITY (SUPPLEMENTAL SITE SELECTION REPORT)

MAY 1986

NCCPD-S
U.S. Army Corps of Engineers
219 S. Dearborn St.
Chicago, Illinois 60604

SECTION 1

PURPOSE AND NEED FOR ACTION

The existing Federal Navigation Project at Waukegan Harbor was originally authorized by the River and Harbor Act of 14 June 1280 and by subsequent acts of 1882, 1902, 1930, 1945, 1965, and 1970. The harbor was last dredged in 1969. The existing project is described in the main body of the site selection report of which this preliminary assessment is part.

The purpose of the recommended work is to maintain harbor navigation (both commercial and recreational) by periodic dredging to authorized depths in the Federal channel and by maintenance of existing Federal structures. The need for dredging in Waukegan Harbor arises from the periodic formation of shoals and sedimentation, which decrease channel depths to less than what is needed. The estimated backlog of sediments within the Federal channel in 1986 is approximately 135,000 cubic yards (U.S. Army Corps of Engineers, 1984). This includes 75,000 cubic yards of nonpolluted, sandy sediment in the outer channel which will not require confined disposal and 60,000 cubic yards of polluted sediments. In addition, up to 127,500 more cubic yards of polluted harbor sediments outside of the authorized Federal channel may also be dredged. These polluted sediments contain high levels of many contaminants and PCBs between 1 and 50 ppm and will require confined disposal. Dredging is needed in order to maintain the authorized navigation depth and to remove contaminants from the environment. If the harbor is not dredged bottom sediments will continue to build up and PCBs and other pollutants will remain within the aquatic environment.

SECTION 2

ALTERNATIVES

PLANS ELIMINATED FROM FURTHER STUDY

Fifteen alternative sites were evaluated for selection as disposal sites between August 1982 and April 1984. As a result of meetings with the Illinois DOT (Division of Water Resources), Illinois EPA, U.S. EPA, Waukegan Port District, Lake County Planning Commission, and Lake County Health Department, all but three upland sites (sites 1, 4, and 16) were eliminated from further consideration. All fifteen sites were discussed in a preliminary assessment included in the April 1984 site selection report.

Site 9 was eliminated from further consideration at an interagency meeting on 19 May 1983 for environmental reasons, but is again being considered as a CDF site.

NO-ACTION ALTERNATIVE

The no-action alternative would consist of not dredging the Federal navigation channel within the harbor thereby eliminating the need for a confined disposal facility (CDF). The overall environmental conditions will remain as they currently exist except that sediments will continue to build up within the channel.

PROPOSED PLAN (SITE 9)

The proposed plan calls for dredging the Federal navigation channel and other areas within the harbor and placing the polluted sediments within a CDF. The CDF would be filled and capped in one season. It would be located at Site 9 of the previous site selection study (U.S. Army Corps of Engineers, 1984). This site is located in Lake Michigan adjacent to the south jetty wall of Waukegan Harbor (Plate 1). Four CDF plans are proposed near the mouth of the Waukegan River (Plans 9A1, 9A2, 9B1, and 9B2). They vary in shape and size, but are located in almost exactly the same location at Site 9. This proposed plan is discussed in detail in the supplemental site selection report of which this assessment is part.

COMPARATIVE IMPACTS OF ALTERNATIVES

Since four CDF plans are proposed for the same site and vary only in shape and size, their environmental impacts will be relatively equal. The significant adverse environmental impacts of maintenance dredging and CDF construction/operation would be 1) a temporary increase in turbidity during dredging and construction and 2) loss of about 15 acres of aquatic habitat through conversion to landfill. The principal adverse impact of the no-action plan would be the hindrance to navigation resulting from accumulation of sediment in the Federal channel and potential for continued PCB contamination of Lake Michigan.

SECTION 3

AFFECTED ENVIRONMENT

GENERAL ENVIRONMENTAL CONDITIONS

The Waukegan Harbor study area lies along Lake Michigan in Lake County, Illinois. The area is primarily residential and commercial/industrial. The area immediately surrounding the harbor and the proposed CDF site is primarily composed of active and abandoned industries.

The area experiences warm, humid summers and cold snowy winters. Average precipitation is around 33 inches per year including an average of 39 inches of snowfall. In summer the average temperature is 71°F while in winter the average temperature is 25°F. Area weather is controlled, in part, by the "lake effect". In late fall and winter air masses that are initially very cold often reach the area after tempered by passage over the lake. In late spring and summer air masses reaching the area from the north, northeast, or east are cooler because of the movement over the Great Lakes.

Lake County is in the Wheaton Morainal country of the Great Lakes section of the Central Lowland province. In general, it has gently sloping relief and poorly defined drainage patterns. Many drainage ways terminate in marshes and depressions. The extreme eastern edge of the county for two to three miles inland drains into Lake Michigan which serves as a water source for most of Waukegan and surrounding communities (U.S. Army Corps of Engineers, 1984).

PHYSICAL AND GROUNDWATER RESOURCES

The selected site for the proposed CDF is an open water location, with depths of 5 to 10 feet along a rubble/riprap filled shoreline, in a semi-deserted industrial area near the mouth of the Waukegan River.

No use of groundwater for industrial, commercial, municipal, or residential purposes is known near the proposed CDF.

SEDIMENT QUALITY

Physically the bottom sediments of the Federal channel at Waukegan Harbor are of two basic types. The bottom sediments along the north pier and in the entrance channel are mostly sand and silty-sand. These sediments most probably represent littoral drift, or sand blown over the north pier from the beach area above of the harbor. The second basic type of bottom sediments in Waukegan Harbor are sandy-clay and silts present in the inner harbor areas.

Chemically, the sediments of Waukegan Harbor were evaluated based on the "Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments" (U.S. Environmental Protection Agency, 1977). These guidelines were developed to meet the need for "immediate decisions regarding the disposal of dredged material". The guidelines are based on several assumptions including:

> "The variability of the sampling and analytical techniques is such that the assessment of any samples must be based on all factors and not on any single parameter with the exception of mercury and polychlorinated biphenyls (PCB's)."

The sand and silty-sand sediments were generally not polluted with metals or organic contaminants. A summary of the pollution classification of samples from this area is shown on Table 1.

The sandy-clay and silty sediments of the inner harbor areas are characterized as "moderately" to "heavily polluted" with some heavy metals and "moderately polluted" with organic matter and nutrients. A summary of the pollutional classification of these sediment samples is shown in Table 2.

The concentration of PCB's in the bottom sediments of Waukegan Harbor varies with location and depth. The U.S. Environmental Protection Agency (1981) divided the harbor into areas of specific PCB concentrations (Plate 3 of Site Selection Study). All areas of the Federal channel are identified as having PCB concentrations less than 50 ppm. Grab and core samples of the sandy-clay and silty sediments of the inner harbor contained PCB levels well below 50 ppm (U.S. Army Corps of Engineers, 1983). Analysis of the silty-sand and sand sediments showed PCB concentrations less than 1.0 ppm throughout (U.S. Army Corps of Engineers, 1981).

Elutriate tests are designed to demonstrate the release or solubilization of contaminants during dredging and/or disposal. The standard elutriate test was developed to evaluate the impacts of open water disposal of hydraulically dredged materials. A sediment and water mixture is prepared and agitated. The soluble fraction is then analyzed for contaminants. Standard elutriate tests conducted with Waukegan Harbor sediments (U.S. Army Corps of Engineers, 1982) demonstrated little or no release of contaminants into solution. These results are in agreement with the findings of the Corps' Dredged Material Research Program which conducted exhaustive testing of dredged material around the country. Most heavy metals were found to be tightly bound to the silty-clay particles of urban sediments.

Chlorinated hydrocarbons are very hydrophobic substances. PCB's in the environment are adsorbed onto soil/sediment particles. In Waukegan Harbor the PCB's present are tightly bound to the organic silts and clays of the upper harbor and are not readily leached into solution.

Table 1 Summary of pollution classification of sand and silty-sand sediment samples

PARAMETER	Non-Polluted	Moderately Polluted	Heavily Polluted
Volatile Solids	19		
Chemical Oxygen Demand	19		
Oil and Grease	19		
Ammonia-Nitrogen	17	1	1
Total Kjeldahl Nitrogen	18	1	
Phosphorous	19		
Cyanide	13	2	1
Arsenic	4	10	5
Barium	15	4	
Cadmium	*	*	
Chromium	18		1
Copper	9	5	5
Iron	19		
Lead	18		1
Manganese	16	3	
Mercury	*	*	
Nickel	19		
Zinc	16	2	1

* lower limits not established

Table 2 Summary of pollution classification of sandy-clay and silty sediment samples

PARAMETER	Non-Polluted	Moderately Polluted	Heavily Polluted
Volatile Solids	6	3	5
Chemical Oxygen Demand	7	3	
Oil and Grease	8	2	
Ammonia-Nitrogen	6	4	
Total Kjeldahl Nitrogen	6	4	
Phosphorous	10		
Cyanide	6	3	1
Arsenic		4	11
Barium	3	8	4
Cadmium	*	*	1
Chromium	9	5	1
Copper	2	3	5
Iron	10		
Lead	5	2	8
Manganese	3	6	1
Mercury	*	*	
Nickel	10		
Zinc	3	5	2

* lower limits not established

An estimated 75,000 cubic yards of sand and silty-sand sediments having little or no organic or metal contaminants and PCB levels less than 1.0 ppm will require removal. These sediments could be used as beach nourishment, construction fill, or disposed of in open water. An estimated 187,500 cubic yards of polluted sandy-clay and silty sediments from the Federal channel and other areas of the harbor will require removal and placement in a CDF.

WATER QUALITY

At the present time extensive, recent water quality data for Waukegan Harbor and the Lake Michigan shoreline near Waukegan is lacking. However, the U.S. EPA reports that PCB levels in harbor waters, nearshore area waters, and open lake waters are all exceeding current water quality standards. These elevated levels are of concern due to bioaccumulation in fish and possible human contamination by eating these fish. PCB levels in open lake waters range from 5 to 10 ppt (parts per trillion). and up to 50 ppt in nearshore waters. These levels are substantially above U.S. EPA recommended levels of one ppt or less which is designed to reduce PCB's in fish to levels that are acceptable for human consumption. PCB levels in Waukegan Harbor waters are substantially higher and range from less than 100 ppt in the harbor channel to several thousand ppt in Slip #3 (U.S. Environmental Protection Agency 1981).

These PCB levels are presently not considered to be a threat to the auxiliary public water supply intake which is located within the harbor channel and is used only one or two days a year. Monitoring of water taken in during periods of use has always shown PCB levels well below the current U.S EPA recommended maximum of one ppb (1,000 ppt). In addition, this water is treated before public use and PCB's have not been detected in the treated water (U.S. Environmental Protection Agency 1981).

As this project progresses more water quality information will be incorporated into future reports. Water sampling and analysis for other contaminants will be obtained as necessary at the harbor, proposed CDF site, and near shore waters near the harbor.

ACUATIC COMMUNITIES

Research on present conditions in the study area (Lake Michigan near the mouth of the Waukegan River) is not available. The closest location with available data to the study area is approximately 2 miles north (near the Waukegan Generating Station). Stations 23, 25 and 27 of an investigation by Commonwealth Edison (1972) refer to a sampling location 2 miles north of the study area at depth contours of 10 ft, 20 ft and 60 ft, respectively, for phytoplankton and zooplankton. Stations 23, 24, 25, 26 and 41, 42, 43, 44 refer to 10, 20, 30 and 40 feet contours, respectively for 8 locations in the same area for benthic invertebrates. Farther north of this area, the investigators had 12 more phytoplankton and zooplankton stations and 32 more northerly sites for benthos. Six sampling zones were established between station 23 and Zion for fish sampling. Since fish are far more mobile than invertebrates all six zones and all methods used in this investigation are considered near the study area (Lake Michigan near the mouth of the Waukegan River).

Phytoplankton

The phytoplankton in Lake Michigan is dominated by diatoms with blue-green and occasionally green algae. The southern end of the lake (Chicago area) has two major phytoplankton (blooms) pulses: one in spring, the other in the fall. (Great Lakes Basin Commission (GLBC, 1976). The spring pulse consists almost entirely of diatoms, including species of Asterionella , Cyclotella, Fragilaria, Stephanodiscus, Tabellaria and Melosira; but populations of blue-green algae, for example Microcystis and Aphanizomenon, mix with these diatoms in the fall pulse. Pilings and submerged structures are covered with mats of green algae (usually Cladophera) up to several inches long (USACE, 1969; verified by telephone conversation with Bill Schmeelk, MSDGC on 4-23-86 as a still viable description of southern Lake Michigan phytoplankton).

Industrial Biotest Laboratories, Inc working for Commonwealth Edison (CEC) in 1972 identified 349 taxa representing 116 genera from six algal divisions in Lake Michigan near Waukegan and Zion, Illinois (CEC, 1972). The most abundant (dominant) taxa for the area near the Waukegan Generating Station are listed in Table 3.

The dominant phytoplankton are the diatoms, Stephanodiscus binderanus and S. hantzchii vel tenuis by number and the diatom, Rhizosolenia eriensis by volume in the three stations nearest the study area. The inshore station (23) had the greatest abundance of Chlorophyta (Green algae), total phytoplankton and Tabellaria flocculosa than any other stations in the investigation.

An associated part of the phytoplankton investigation was a productivity study using light-dark bottle estimates of carbon fixation rates and chlorophyll a concentrations.

Since station 23 had significantly reduced phytoplankton productivity (carbon fixation rates) by comparison with other stations in this investigation, these data may not be very representative of what might be expected in the study area farther from the impacts of the Waukegan Generating Station. Total Chlorine at Station 23 (0.14 mg/l) may have an inhibiting effect on the nearshore biota (due to the combined effect of the power plant and the North Shore Sanitary District's Waukegan Sewage Treatment Plant). However mean yearly enumerations of the majority of the algal groups and dominant taxa were greater at these three stations than at more northerly ones.

Zooplankton

Diaptomid copepods dominate the biomass of the zooplankton; however, protozoans and rotifers may also be present in great numbers. Cladocerans are abundant during the summer. There appears to be one major zooplankton peak annually. The oppossum shrimp, Mysis relicta, and the amphipod, Pontoporeia affinis, are dominant in deep, colder waters. The shallow water fauna are somewhat typical of smaller lakes. Benthic species include midge larvae, oligochaete worms and sphaeriid clams. Also included are snails and nymphs of the mayfly and caddisfly (USACE, 1969).

Table 3. Grand mean ranking of major algal divisions and dominant taxa near Zion and Waukegan, Illinois, 1972. (from CEC, 1972)

Taxon	Location 23 Rank	Location 23 Reporting units/ml	Location 23 % Occurrence	Location 25 Rank	Location 25 Reporting units/ml	Location 25 % Occurrence	Location 27 Rank	Location 27 Reporting units/ml	Location 27 % Occurrence
Centrales	1	1302		1	1365		1	810	
Pennales	2	560		2	508		2	528	
Bacillariophyta total	-	1862	88.1	-	1873	88.4	-	1338	83.6
Chlorophyta	4	60	2.8	4	50	2.4	4	47	2.9
Chrysophyta	5	32	1.5	5	38	1.8	5	44	1.8
Cyanophyta	3	154	7.3	3	134	6.3	3	168	10.5
Total Phytoplankton	-	2113	100	-	2119	100	-	1601	100
<u>Stephanodiscus binderanus</u>	1	255	12.1	1	287	13.5	4	128	8.0
<u>Stephanodiscus hantzschii</u> vel <u>tenuis</u>	2	233	11.0	2	268	12.7	3	143	8.9
<u>Rhizosolenia eriensis</u>	5	96	4.5	4	102	4.8	7	57	3.6
<u>Tabellaria flocculosa</u>	3	135	6.4	3	129	6.1	1	159	9.9
<u>Fragilaria crotonensis</u>	4	130	6.2	5	99	4.7	2	150	9.4
<u>Asterionella formosa</u>	6	77	3.6	6	82	3.9	6	62	3.9
<u>Oocystis lacustris</u>	9	1	0.1	9	2	0.1	9	2	0.1
<u>Dinobryon divergens</u>	8	10	0.5	8	14	0.7	8	19	1.2
<u>Coelosphaerium naegelianum</u>	7	75	3.6	7	78	3.7	5	100	6.3

Biovolume

Taxon	Location 23 Rank	Location 23 Microliters/liter	Location 23 % Occurrence	Location 25 Rank	Location 25 Microliters/liter	Location 25 % Occurrence	Location 27 Rank	Location 27 Microliters/liter	Location 27 % Occurrence
Centrales	1	0.455		1	0.443		1	0.374	
Pennales	2	0.256		2	0.254		2	0.312	
Bacillariophyta total	-	0.711	78.5	-	0.697	74.5	-	0.686	69.7
Chlorophyta	3	0.109	12.0	3	0.119	12.7	3	0.110	11.2
Crysophyta	4	0.046	5.1	4	0.062	6.6	5	0.066	6.7
Cyanophyta	5	0.031	3.4	5	0.042	4.5	3	0.110	11.2
Total Phytoplankton	-	0.906	100	-	0.936	100	-	0.904	100
<u>Stephanodiscus binderanus</u>	2	0.131	14.5	2	0.141	15.1	2	0.114	11.6
<u>Stephanodiscus hantzschii</u> vel <u>tenuis</u>	4	0.036	3.9	7	0.031	3.3	7	0.022	2.2
<u>Rhizosolenia eriensis</u>	1	0.234	25.8	1	0.258	27.6	3	0.110	11.2
<u>Tabellaria flocculosa</u>	3	0.102	11.3	3	0.115	12.3	1	0.164	16.7
<u>Fragilaria crotonensis</u>	5	0.031	3.4	6	0.033	3.5	4	0.053	5.4
<u>Asterionella formosa</u>	8	0.014	1.6	8	0.017	1.8	8	0.016	1.6
<u>Oocystis lacustris</u>	7	0.020	2.2	4	0.050	5.3	6	0.037	3.8
<u>Dinobryon divergens</u>	6	0.023	2.5	5	0.034	3.6	5	0.043	4.4
<u>Coelosphaerium naegelianum</u>	9	0.002	0.2	9	0.002	0.2	9	0.002	0.2

Industrial Biotest also sampled stations 23, 25 and 27 for zooplankton and summaries of this investigation can be found in Table 4. Note that during this investigation Cladocera, especially Bosmina longirostris dominate the zooplankton catch and the percent occurrence of this organism decreases as one proceeds away from shore (from 50% to 21%). B. longirostris was the dominant organism caught in this investigation (CEC, 1972). The fact that other Bosmina species are not taken leads some investigators to use B. longirostris as a replacement for B. coregoni due to increased eutrophication. However, B. longirostris was present in oligotrophic Lake Huron as early as 1915. Also, Eurytemora affinis and Cyclops vernalis are recent additions to the zooplankton of Lake Michigan (GLBC, 1976).

Benthic invertebrates

Oligochaete worm populations in Lake Michigam are concentrated in the southern end while amphipods are concentrated in more northern nearshore areas producing a north-south gradient in the ratio of the two taxa. Distributions of Peloscolex multisetosus and Limnodrilus cervix (tubificids) seem to concentrate near larger cities indicating pollution tolerance in these two species. Chicago is unique in that these two species are not very common near its shores indicating less pollution since most sewage effluent is passed away from Lake Michigan to the Illinois River (GLBC, 1976).

Eight localities near the Waukegan Generating Station (approximately 2 miles North of the study area) were sampled for benthic invertebrates in 1972 by Industrial Biotest (CEC,1972). Table 5 lists the total numbers of each taxa for all 8 stations (23-26 and 41-44), depth contours 10-40 ft. in each transect.

In the Waukegan area the mean abundance of benthos increased with sample depth as did total organic carbon content of the sediment. Crustacae were the most abundant benthic organisms represented almost entirely by the amphipod Pontoporeia affinis (more abundant at the Waukegan stations than at more northern stations. Second in abundance throughout the 40 stations were oligochaete worms. Potamothrix moldaviensis and Limnodrilus hoffmeisteri were the dominant tubificids which also had higher mean abundance in the Waukegan area as did sphaeriidae (fingernail clams). Midges (Chironomidae) were low in abundance tthroughout the investigation and gastropods were rare at all locations (CEC, 1972).

Table 6 reviews the number of zooplankton and benthic taxa reported in Lake Michigan the Great Lakes Commission and Commonwealth Edison Company. 194 taxa have been reported in Lake Michigan and 119 taxa were reported near the study area (2 miles North) in 1972 (GLBC, 1976; CEC, 1972).

Fish

Recreational fishing is important in the Waukegan area. Coho salmon have been stocked to supplement the lake trout fishery. Lake run brook trout and rainbow trout, as well as chinook salmon, have also been stocked. Perch, walleye, bass, carp, drum and bullheads are also part of the recreational fishery. Commercial fishing has always been an important

Table 4. Mean abundance of zooplankton with species ranked according to abundance for locations in southwestern Lake Michigan near Waukegan, Illinois, 1972 (from CEC,1972).

Location 23 (Waukegan)		
Organism	Organisms/ m^3	% Occurrance
Total Zooplankton	87,338	
Cladocera	49,190	56.3
Copepoda	27,752	31.8
Nauplii	3,585	4.1
Calanoid copeopdites	1,777	2.0
Cyclopoid copepodites	16,998	19.5
Rotifera	10,396	11.9
Species		
Bosmina longirostris	44,780	51.3
Daphnia retrocurva	3,668	4.2
Tropocyclops prasinus	2,401	2.7
Cyclops bicuspidatus thomasi	1,689	1.9
Diaptomus spp. (total)	1,147	1.3
Ceriodaphnia spp.	408	0.5
Diaptomus ashlandi male	367	0.4
Daphnia galeata mendotae	165	0.2
Eubosmina coregoni	120	0.1
Diaptomus minutus male	97	0.1
Diaptomus oregonensis male	90	0.1
Limnocalanus macrurus	51	0.1
Leptodora kindtii	44	0.1
Eurytemora affinis	41	-[a]
Cyclops vernalis	30	-
Diaptomus sicilis male	16	-
Epischura lacustris	3	-
Chydorus sphaericus	2	-

Table 4. Continued

Location 25 (Waukegan		
Organism	Organisms/ m^3	% Occurrence
Total Zooplankton		
Cladocera	18,904	34.4
Copepoda	21,574	39.2
Nauplii	5,153	9.4
Calanoid copepodites	5,984	10.9
Cyclopoid copepodites	7,181	13.1
Rotifera	14,517	26.4
Species		
Bosmina longirostris	16,731	30.4
Daphnia retrocurva	1,645	2.4
Diaptomus spp. (total)	1,324	2.4
Cyclops bicuspidatus thomasi	780	1.4
Tropocyclops prasinus	644	1.2
Diaptomus ashlandi male	502	0.9
Ceriodaphnia spp.	183	0.3
Eubosmina coregoni	147	0.3
Diaptomus minutus male	126	0.2
Diaptomus oregonensis male	73	0.1
Daphnia galeata mendotae	65	0.1
Epischura lacustris	39	0.1
Limnocalanus macrurus	34	0.1
Daphnia longiremis	16	- [a]
Diaptomus sicilis male	15	-
Eurytemora affinis	13	-
Diaphanosoma spp.	13	-
Holopedium gibberum	10	-

Location 27 (Waukegan)		
Organism	Orgamisms/ m^3	% Occurrance
Total Zooplankton	44,736	
Cladocera	12,611	28.2
Copepoda	21,416	47.9
Nauplii	3,607	8.1
Calanoid copepodites	6,030	13.5
Cyclopoid copepodites	8,967	20.0
Rotifera	10,709	23.9

Table 4. Continued

Species		
Bosmina longirostris	9,632	21.5
Daphnia retrocurva	1,899	4.2
Diaptomus spp. (total)	1,634	3.7
Cyclops bicuspidatus thomasi	840	1.9
Diaptomus ashlandi male	626	1.4
Eubosmina coregoni	482	1.1
Tropocyclops prasinus	297	0.7
Holopedium gibberum	211	0.5
Daphnia galeata mendotae	154	0.3
Diaptomus minutus male	143	0.3
Ceriodaphnia spp.	118	0.3
Diaphanosoma spp.	64	0.1
Diaptomus oregonensis male	56	0.1
Daphnia longiremis	40	0.1
Diaptomus sicilis male	38	0.1
Limnocalanus macrurus	14	- [a]
Harpacticoids	13	-
Epischura lacustris	10	-
Leptodora kindtii	10	-
Cyclops vernalis	3	-

[a] Average % occurrence less than 0.1%

Table 5. Mean abundance of benthos with taxa ranked according to abundance for [illegible] in southwestern Lake Michigan [illegible]

South Transect Location	23 Mean/m²	23 % of Total Benthos	24 Mean/m²	24 % of Total Benthos	25 Mean/m²	25 % of Total Benthos	26 Mean/m²	26 % of Total Benthos
TOTAL BENTHOS	1016.2		9222.9		10690.7		10019.3	
TOTAL AMPHIPODA	825.5	81.23	6134.8	66.52	2395.3	22.40	345.3	[illegible]
TOTAL OLIGOCHAETA	125.5	12.35	1194.2	12.95	4698.5	43.20	5740.7	[illegible]
TUBIFICIDAE	119.3	11.74	1103.0	11.96	4116.7	38.51	5524.0	[illegible]
Immatures without capilliform chaetae	88.0	8.69	894.5	9.70	3263.3	30.52	4627.3	[illegible]
Immatures with capilliform chaetae	0.0	0.0	100.7	1.09	52.0	0.49	149.5	[illegible]
NAIDIDAE	0.0	0.0	1.5	0.02	3.0	0.03	1.5	[illegible]
ENCHYTRAEIDAE	0.0	0.0	0.0	0.0	0.0	0.0	4.7	[illegible]
TOTAL PELECYPODA	31.2	3.07	1469.2	15.93	2920.0	27.34	1434.5	[illegible]
TOTAL CHIRONOMIDAE	24.8	2.44	106.8	1.16	316.2	2.36	238.7	[illegible]
TOTAL GASTROPODA	7.7	0.76	270.8	2.94	239.2	2.24	39.0	[illegible]
ORGANISMS:								
Pontoporeia affinis	825.5	81.23	4468.2	48.46	2395.3	22.4	345.3	[illegible]
Pisidium sp.	18.8	1.85	619.0	6.71	1512.0	14.14	589.7	[illegible]
Cryptochironomus sp.	14.0	1.38	0.0	0.0	3.0	0.03	[illegible]	[illegible]
Potamothrix moldaviensis	12.0	1.21	9.2	0.10	1.5	0.01	[illegible]	[illegible]
Unidentified Sphaeriidae	7.8	0.77	335.8	4.18	530.8	4.96	130.7	[illegible]
Limnodrilus profundicola	7.8	0.77	0.0	0.0	0.0	0.0	[illegible]	[illegible]
Valvata perdepressa	7.7	0.77	208.0	2.25	148.2	1.39	21.3	[illegible]
Limnodrilus hoffmeisteri	4.7	0.46	76.8	0.83	552.8	5.17	453.0	[illegible]
Stylodrilus heringianus	4.7	0.46	62.8	0.68	475.8	4.45	100.3	[illegible]
Chironomus sp.	4.7	0.46	12.7	0.14	31.5	0.29	51.3	[illegible]
Procladius sp.	3.2	0.31	70.8	0.77	241.0	2.25	121.2	[illegible]
Peloscolex multisetosus multisetosus	3.2	0.31	1.5	0.02	6.3	0.06	571.7	[illegible]
Sphaerium sp.	1.5	0.15	376.5	4.08	412.5	3.86	0.0	[illegible]
Sphaerium nitidum	1.5	0.15	3.0	0.03	182.7	1.71	448.3	[illegible]
Aulodrilus pluriseta	1.5	0.15	1.5	0.02	77.2	0.72	417.0	[illegible]
Tubifex [illegible]	1.5	0.15	0.0	0.0	12.5	0.12	124.0	[illegible]
Monodiamesa tuberculata	1.5	0.15	15.5	0.17	12.5	0.12	17.2	[illegible]
Nais [illegible]	1.5	0.15	0.0	0.0	3.2	0.03	0.0	[illegible]
Uncinais uncinata	1.5	0.15	3.2	0.03	1.5	0.01	0.0	[illegible]
Paracladopelma sp.	1.5	0.15	0.0	0.0	1.5	0.01	0.0	[illegible]
Sphaerium fabale	1.5	0.15	9.3	0.10	0.0	0.0	0.0	[illegible]
Pisidium [illegible]	0.0	0.0	35.2	0.38	252.0	2.36	103.3	[illegible]
Nematoda	0.0	0.0	9.3	0.10	119.5	1.12	611.0	[illegible]
[illegible]	0.0	0.0	25.1	0.27	82.0	0.77	35.2	[illegible]
[illegible]	0.0	0.0	55.2	0.60	77.2	0.72	9.0	[illegible]
Limnodrilus spiralis	0.0	0.0	11.0	0.12	29.8	0.28	40.3	[illegible]
Limnodrilus hoffmeisteri (variant)	0.0	0.0	0.0	0.0	20.3	0.19	[illegible]	[illegible]
Potamothrix vejdovskyi	0.0	0.0	6.1	0.07	85.1	0.80	271.3	[illegible]
Sphaerium striatinum	0.0	0.0	20.1	0.22	17.0	0.16	[illegible]	[illegible]
Heterotrissocladius sp.	0.0	0.0	3.2	0.03	14.2	0.13	18.3	[illegible]
Pisidium [illegible]	0.0	0.0	0.0	0.0	12.7	0.12	[illegible]	[illegible]
Ilyodrilus templetoni	0.0	0.0	0.0	0.0	9.5	0.09	[illegible]	[illegible]
Valvata sincera	0.0	0.0	0.0	0.0	7.7	0.07	[illegible]	[illegible]
[illegible] sp.	0.0	0.0	9.5	0.10	4.7	0.04	[illegible]	[illegible]
[illegible] sp.	0.0	0.0	4.7	0.05	4.7	0.04	[illegible]	[illegible]
Parakiefferiella sp.	0.0	0.0	0.0	0.0	4.7	0.04	[illegible]	[illegible]
Dina microstoma	0.0	0.0	0.0	0.0	4.5	0.04	[illegible]	[illegible]
Limnodrilus claparedeianus	0.0	0.0	0.0	0.0	3.2	0.03	[illegible]	[illegible]
Unidentified Hydracarina	0.0	0.0	0.0	0.0	3.2	0.03	[illegible]	[illegible]
Procladius (Psilotanypus) bellus	0.0	0.0	0.0	0.0	3.8	0.03	[illegible]	[illegible]
Valvata sincera [illegible]	0.0	0.0	4.7	0.05	3.8	0.03	[illegible]	[illegible]
Sphaerium corneum	0.0	0.0	19.0	0.21	3.0	0.03	[illegible]	[illegible]
[illegible] michiganensis	0.0	0.0	1.5	0.02	3.0	0.03	[illegible]	[illegible]
Spirosperma sp.	0.0	0.0	3.0	0.03	1.5	0.01	[illegible]	[illegible]
Valvata tricarinata simplex	0.0	0.0	0.0	0.0	1.5	0.01	[illegible]	[illegible]
Tubifex tubifex	0.0	0.0	0.0	0.0	1.5	0.01	[illegible]	[illegible]
Limnodrilus udekemianus	0.0	0.0	1.5	0.02	1.5	0.01	[illegible]	[illegible]
Nais sp.	0.0	0.0	0.0	0.0	1.5	0.01	[illegible]	[illegible]
[illegible] lacustris	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]
[illegible]	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]
Aulodrilus americanus	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]
Limnodrilus cervix	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]
Peloscolex multisetosus longidentus	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]
Helobdella stagnalis	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]
Glossiphonia complanata	0.0	0.0	1.5	0.02	0.0	0.0	[illegible]	[illegible]
Asellus sp.	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]
Micropsectra sp.	0.0	0.0	0.0	0.0	0.0	0.0	25.2	[illegible]

Table 5. (continued)

North Transect Location	41 Mean/m²	41 % of Total Benthos	42 Mean/m²	42 % of Total Benthos	43 Mean/m²	43 % of Total Benthos	44 Mean/m²	44 % of Total Benthos
TOTAL BENTHOS	2383.8		7284.00		10587.8		20792.5	
TOTAL AMPHIPODA	1996.3	84.0	5927.5	81.0	3720.3	35.2	697.0	[illegible]
TOTAL OLIGOCHAETA	337.2	14.2	412.7	5.7	3822.0	36.2	16172.0	[illegible]
TUBIFICIDAE	290.5	12.2	337.2	4.6	2846.8	26.9	15985.0	[illegible]
Immature without capilliform chaetae	207.8	8.7	229.2	3.2	2282.2	21.6	9140.0	[illegible]
Immature with capilliform chaetae	0.0	0.0	2.2	0.0	42.5	0.4	198.5	[illegible]
NAIDIDAE	9.5	0.4	0.0	0.0	4.8	0.1	0.0	[illegible]
ENCHYTRAEIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]
TOTAL CHIRONOMIDAE	35.0	1.5	32.8	0.5	99.3	0.9	411.0	[illegible]
TOTAL PELECYPODA	16.5	0.7	779.2	10.7	2525.7	24.8	2590.0	[illegible]
TOTAL GASTROPODA	4.5	0.2	115.5	1.6	132.3	1.3	172.0	[illegible]
ORGANISMS:								
Pontoporeia affinis	2287.3	95.1	5927.5	81.4	6382.7	60.3	697.0	1.4
Stylodrilus heringianus	271.5	11.4	75.5	1.0	966.3	9.2	277.3	[illegible]
Limnodrilus hoffmeisteri	45.0	1.9	18.8	0.3	382.8	3.6	2562.2	[illegible]
Cryptochironomus sp.	30.5	1.3	2.3	0.0	0.0	0.0	4.8	[illegible]
Limnodrilus profundicola	19.0	0.8	2.3	0.0	0.0	0.0	7.0	[illegible]
Pisidium sp.	14.2	0.6	276.5	3.8	1025.2	9.7	1228.2	[illegible]
Potamothrix moldaviensis	11.8	0.5	9.2	0.1	9.5	0.1	33.0	[illegible]
Piguetiella michiganensis	9.5	0.4	0.0	0.0	4.8	0.0	0.0	[illegible]
[illegible]	4.8	0.2	4.8	0.1	85.0	0.8	200.5	[illegible]
Limnodrilus angustipenis	4.8	0.2	0.0	0.0	0.0	0.0	0.0	[illegible]
Paracladopelma sp.	4.5	0.2	0.0	0.0	0.0	0.0	0.0	[illegible]
Valvata perdepressa	4.5	0.2	89.8	1.2	108.5	1.0	14.0	[illegible]
Hydracarina	2.2	0.1	2.3	0.0	0.0	0.0	7.0	[illegible]
Nematoda	2.2	0.1	7.0	0.1	28.2	0.3	106.5	[illegible]
Sphaerium striatinum	2.2	0.1	33.0	0.2	11.5	0.1	2.2	[illegible]
Limnodrilus spiralis	0.0	0.0	2.3	0.0	0.0	0.0	28.2	[illegible]
[illegible] tuberculata	0.0	0.0	21.5	0.3	44.8	0.4	2.2	[illegible]
Lymnaea auricularia	0.0	0.0	25.8	0.4	49.8	0.5	101.5	[illegible]
Sphaerium sp.	0.0	0.0	52.0	0.7	276.2	2.6	2.2	[illegible]
Pisidium idahoense	0.0	0.0	2.3	0.0	2.2	0.0	7.0	[illegible]
Sphaerium corneum	0.0	0.0	9.2	0.1	4.5	0.0	0.0	[illegible]
Sphaerium fabale	0.0	0.0	7.0	0.1	2.2	0.0	0.0	[illegible]
Hydropsyche sp.	0.0	0.0	2.3	0.0	0.0	0.0	0.0	[illegible]
Procladius sp.	0.0	0.0	7.0	0.1	54.5	0.5	239.2	[illegible]
Unidentified Sphaeriidae	0.0	0.0	415.8	5.7	1141.2	10.8	274.0	[illegible]
Sphaerium nitidum	0.0	0.0	0.0	0.0	141.5	1.3	1075.0	[illegible]
Potamothrix vejdovskyi	0.0	0.0	0.0	0.0	49.2	0.5	78.0	[illegible]
Aulodrilus pluriseta	0.0	0.0	0.0	0.0	40.2	0.41	271.8	[illegible]
Pisidium amnicum	0.0	0.0	0.0	0.0	21.0	0.2	259.5	[illegible]
Peloscolex multisetosus multisetosus	0.0	0.0	0.0	0.0	19.0	0.2	728.0	[illegible]
Ilyodrilus templetoni	0.0	0.0	0.0	0.0	16.5	0.2	52.0	[illegible]
Glossiphonia complanata	0.0	0.0	0.0	0.0	6.8	0.0	45.0	[illegible]
Spirosperma sp.	0.0	0.0	0.0	0.0	4.8	0.0	0.0	[illegible]
Uncinais uncinata	0.0	0.0	0.0	0.0	2.2	0.0	0.0	[illegible]
Aulodrilus americanus	0.0	0.0	0.0	0.0	2.2	0.0	144.0	[illegible]
Limnodrilus claparedeianus	0.0	0.0	0.0	0.0	2.2	0.0	9.2	[illegible]
Ostracoda	0.0	0.0	0.0	0.0	2.2	0.0	2.2	[illegible]
Tubifex tubifex	0.0	0.0	0.0	0.0	2.2	0.0	23.5	[illegible]
Dina microstoma	0.0	0.0	0.0	0.0	2.2	0.0	30.5	[illegible]
Chironomus sp.	0.0	0.0	0.0	0.0	0.0	0.0	92.2	[illegible]
Valvata sincera nylanderi	0.0	0.0	0.0	0.0	0.0	0.0	78.0	[illegible]
Micropsectra sp.	0.0	0.0	0.0	0.0	0.0	0.0	68.5	[illegible]
Peloscolex multisetosus longidentus	0.0	0.0	0.0	0.0	0.0	0.0	47.2	0.2
Helobdella stagnalis	0.0	0.0	0.0	0.0	0.0	0.0	42.5	0.2
Limnodrilus cervix	0.0	0.0	0.0	0.0	0.0	0.0	21.2	[illegible]
Unidentified Glossiphoniidae	0.0	0.0	0.0	0.0	0.0	0.0	7.0	[illegible]
[illegible] sp.	0.0	0.0	0.0	0.0	0.0	0.0	4.3	[illegible]
[illegible] sp.	0.0	0.0	0.0	0.0	0.0	0.0	4.8	[illegible]
Dina parva	0.0	0.0	0.0	0.0	0.0	0.0	4.8	[illegible]
Hyalella azteca	0.0	0.0	0.0	0.0	0.0	0.0	4.5	[illegible]
Heterotrissocladius sp.	0.0	0.0	0.0	0.0	0.0	0.0	4.3	[illegible]
Peloscolex ferox	0.0	0.0	0.0	0.0	0.0	0.0	2.2	[illegible]
Unidentified Erpobdellidae	0.0	0.0	0.0	0.0	0.0	0.0	2.2	[illegible]
Cladotanytarsus sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.2	[illegible]
Asellus sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.2	[illegible]
Thienemanniella group	0.0	0.0	0.0	0.0	0.0	0.0	2.2	[illegible]

Table 6. Number of Species of Major Invertebrate Taxa Reported in Lake Michigan as of 1976. (from GLBC, 1976 and CEC, 1972)

	Waukegan-Zion area	Lake Michigan
Protozoa (unicellular animals)	12	20
Coelenterata (hydra and jellyfish)	1	2
Rotatoria		64
Copepods	15	15
Cladocera (water fleas)	24	20
Porifera (sponges)		1
Turbellaria (flatworms)	1	1
Bryozoa (moss animals)		2
Nematoda (roundworms)	1	1
Tubificidae (sludgeworms)	16	24
Enchytraeiae	1	1
Naididae	5	12
Lumbriculidae	1	-
Polychaetra	-	-
Hirudinae (leeches)	5	1
Sphaeriidae (fingernail clams)	7	19
Unionidae (mussels)		-
Gastropoda (snails)	6	3
Tardigrada (Waterbears)		1
Hydracarina (water mites)	1	1
Ostracoda (seed shrimp)	1	1
Mysidacea (opposum shrimp)	1	1
Isopoda (aquatic sowbugs)	2	-
Amphipoda (scuds)	2	2
Decopoda (shrimp and crayfish)		-
Chironomidae (midges)	15	1
Other Diptera		-
Neuroptera		-
Hemiptera		-
Plecoptera (stoneflies)	1	-
Odonata (damsel flies)		-
Trichoptera (caddisflies)		-
Ephemeroptera (mayflies)		1
Coleoptera (beetles)	1	-
Total species	119	194

activity in the Lake Michigan basin, although the catch has declined in dollar value over the years. Originally, lake trout, whitefish, and herring were the principal catches. As these declined, yellow perch and chub made up a large portion of the catch. Recently, even these have been replaced as dominant catch components; carp, whitefish, chubs and alewives now dominate the catch, with the latter only a marginally economic fish. The dominant species in the commercial catch, ranked according to 1971 landings (in pounds), are as follows: alewife (29,660,000 lbs.), chubs (5,7134,000 lbs.), whitefish (2,894,000 lbs.), and carp (2,464,000 lbs.). The alewife forage base and generally good water quality have made Lake Michigan the top producer of trout and salmon in the Great Lakes (GLBC, 1975).

Yellow perch consistently provided a catch between 1.0 and 3.4 million pounds in the period from 1900-1960. In 1961 the catch doubled to 5 million lbs. and peaked at 5.8 million lbs. in 1964. In 1968 the catch declined to 632,000 lbs. Michigan closed its commercial fishery and populations are recovering. Alewife peaked during its nuisance period (1965-1979) to 41.9 million lbs. in 1967. Current alewife population has stabilized at 25 million lbs/yr. Smelt peaked in 1959 at 9.1 million lbs. and has leveled off to 1.5 million lbs/yr. The Lake Michigan salmonid catch is in excess of 1.7 million fish/yr (GLBC, 1975).

Industrial Biotest sample adult fish by trawl, gill nets and minnow seine north of the study area in 1972 between Zion and Waukegan. This sampling yielded 19,200 lbs consisting of 28 species with alewife and smelt representing 86% by weight and 98% by number. Sport fish (lake trout, chinook and coho salmon, brown and rainbow trout) accounted for 6% of the catch by weight and 1/2% by number. Yellow perch was the 4th most abundant fish taken and were concentrated at depths of <12 feet in the summer. Young of the year alewife, smelt, yellow perch, white sucker and trout-perch were collected as well as eggs and larvae of alewife and smelt indicating spawning in the vicinity. The inshore area under the influence of the Waukegan plume (power generating plant) did not attract larger number of any species of fish. Table 7 lists the relative catch by number and weight of the 28 species taken in this investigation (CEC, 1972).

Table 7. Fish collected in the Waukegan-Zion sampling area, June-December 1972, all sampling methods.

	Species	Total Number	%	Total Weight (Kg)	%
1.	Alewife	231554	74.92	6636.099	76.01
2.	Smelt	70700	22.87	889.510	10.19
3.	Bloater	4018	1.30	368.226	4.22
4.	Yellow perch	1327	0.43	151.643	1.74
5.	Sculpin	353	0.11	2.937	0.03
6.	Spottail shiner	330	0.11	3.992	0.05
7.	Lake trout	221	0.07	393.085	4.50
8.	Fathead minnow	137	0.04	0.207	0.00
9.	White sucker	93	0.03	16.960	0.19

Table 7. Continued

10.	Coho salmon	80	0.03	93.421	1.07
11.	Troutperch	73	0.02	0.710	0.01
12.	Brown trout	38	0.01	45.301	0.52
13.	Chinook salmon	27	0.01	14.628	0.17
14.	Carp	26	0.01	76.810	0.88
15.	Ninespine stickleback	26	0.01	0.071	0.00
16.	Longnose dace	25	0.01	0.106	0.00
17.	Lake whitefish*	16	0.01	19.485	0.22
18.	Rainbow trout	9	0.00	12.709	0.15
19.	Emerald shiner	8	0.00	0.026	0.00
20.	Longnose sucker*	4	0.00	1.540	0.02
21.	Brook stickleback	2	0.00	0.002	0.00
22.	Golden shiner	2	0.00	0.006	0.00
23.	Gizzard Shad	2	0.00	1.190	0.01
24.	Central Mudminnow	1	0.00	0.002	0.00
25.	Largemouth Bass	1	0.00	0.020	0.00
26.	White Crappie	1	0.00	0.085	0.00
27.	Burbot	1	0.00	0.850	0.01
28.	Herring	1	0.00	0.600	0.01
				8727.221 Kg.	
				19199.886 lbs.	

* State Threatened Species

AQUATIC RESOURCES

SUMMARY

All of the aforementioned data was either lakewide or between Zion and Waukegan Generating Station (2 miles North of the study area). No aquatic data is known to exist from the proposed CDF site 9 near the mouth of the Waukegan River or from the harbor where the dredging would occur. Nor is there any known biological data from the Waukegan River inland from the study area. The only other investigations are PCB fish tissue analysis of 16 samples of Waukegan harbor fish and a 30 day exposure of caged (uncontaminated) fish (bluegills and yellow perch) into Slip #3 (Superfund site candidate contaminated with PCB's). The fish tissue analyses resulted in an average PCB concentration of 18 ppm with all samples exceeding the 5 ppm FDA guideline and all but one exceeded the 2 ppm, the new proposed guideline. The second study resulted in 20 ppm PCB levels in bluegills and 12 ppm in yellow perch. After 84 days in cleaner water these levels did not drop below 8 ppm (USEPA, 1981).

TERRESTRIAL RESOURCES

A wide variety of bird species use the Lake Michigan shoreline habitat in the Chicago region (Table 8). Many species migrate through the region and rest and forage on such habitat on a seasonal basis. A preliminary site inspection of the area on 22 April, 1986 revealed fairly heavy use of

Table 8

The Birds of the Chicago Region
Lake Michigan Shoreline

Horned Grebe
Pied-billed Grebe
Eared Grebe
Great Blue Heron
Black-crowned Night Heron *
Double-crested Comorant*
Commaon Loon
Common Goldeneye
Ruddy Duck
Lesser Scaup
Greater Scaup
Common Merganser
Red-breasted Merganser
Canadian Goose
Mallard
Black Duck
Bufflehead
Semipalmated Plover
Killdeer
American Golden Plover
Black-bellied Plover
Piping Plover **
Ruddy Turnstone
Common Snipe
Spotted Sandpiper
Solitary Sandpiper
Greater Yellowlegs
Lesser Yellowlegs
Pectoral Sandpiper
Baird's Sandpiper
Least Sandpiper
Dunlin
Short-billed Dowitcher
Semipalmated Sandpiper
Sanderling
Bonoparte's Bull
Herring Gull
Ring-billed Gull
Forster's Tern *
Common Tern *
Black Tern *
Caspian Tern
Mourning Dove
Chimney Swift
Belted Kingfisher
Horned Lark
Tree Swallow
Bank Swallow
Rough-winged Swallow
Barn Swallow
Purple Martin
Common Crow
Long-billed Marsh Wren
Short-billed Marsh Wren
Catbird
Starling
Myrtle Warbler
Black-throated Green Warbler
Yellow-rumped Warbler
Palm Warbler
Yellowthroat
House Sparrow
Redwinged Blackbird
Brown-headed Cowbird
Common Grackle
Cardinal
Snow Bunting
Indigo Bunting
American Goldfinch
Slate-colored Junco
White-crowned Sparrow
White-throated Sparrow
Song Sparrow
Amercian Kestrel
Peregrine Falcon**
Marsh Hawk*
Golden Eagle
Bald Eagle**

* State Endangered Species.
** Feceral Endangered Species.

the harbor and proposed CDF site by herring gulls (Larus argentatus), ring-billed gulls (L. delawarensis), and bonaparte gulls (L. philadelphia). Many common mergansers (Mergus merganser), scaup (Aythya spp.), mallard ducks (Anas platyrhynchos), and common songbirds were also observed. No mammals or mammal sign was observed. The shore edge habitat at the CDF site consisted of concrete and stone fill material virtually devoid of vegetation.

More detailed site inspections will be needed to determine total wildlife use of the project area over the course of a year's time. Such a study will be accomplished in later planning stages. However, the overall habitat diversity and value to wildlife is fairly low.

Threatened and Endangered Species

The only Federally listed species possibly occurring in the project area as a breeding species are the Indiana bat (Myotis sodalis) and the piping plover (Charadrius melodus). The Indiana bat winters in caves in the south eastern U.S. and uses riparian forested habitat throughout its range for rearing its young. Neither of these habitat types occur in the harbor or CDF site and the bat has never been reported in Lake County (Natural Land Institute, 1981).

The piping plover, however, has historically nested in undisturbed, sandy, shoreline beach areas of Lake Michigan within two miles of Waukegan (Nelson, 1876) and nested at Illinois Beach State Park north of Waukegan as recently as 1975 (Natural Land Institute, 1981). However, this type of sandy, undisturbed habitat is no longer present at Waukegan Harbor or the proposed CDF site. In addition, the Illinois Department of Conservation now considers the piping plover to be extinct as a breeding species from the state of Illinois though it still may occur as a rare summer migrant in the Waukegan area.

In addition, the Federally endangered peregrine falcon (Falco peregrinus) has been observed foraging in Waukegan Harbor during a recent Corps' site inspection and a bald eagle was observed at Illinois Beach State Park in 1971 (Bohler, 1978). They were believed to be migrating through the area as suitable breeding habitat does not exist near Waukegan and these species have never been reported breeding in northeastern Illinois (Natural Land Institute 1981).

State endangered species which may use Lake Michigan shoreline habitat for resting and foraging, especially during migration, include double-crested cormorants (phalacrocorax auritus), black-crowned night herons (Nycticorax nycticorax), Forster's tern (Sterna forsteri), common terns (S. hirundo), black terns (Chlidonias niger), and marsh hawks (Circus cyaneus). Of these only common terns nest on beaches and sandbars along the Lake Michigan shoreline. The other species commonly nest in more inland marshes and lake edges (Natural Lake Institute, 1981). Between 1934-1936 a colony of common terns existed at Waukegan (Ford, 1956). Though the existing filled shoreline habitat around the Waukegan area may still provide some suitable nesting substrate, the area is also highly disturbed by human activities. The last reported nesting of common terns in Lake County occurred in the 1960's at Powerhorn Marsh (Bohlen, 1978).

Two state threatened fish have also been found near Waukegan. They are the lake whitefish (Coregonus clupeaformis) and the longnose sucker (Castomus castomus). Both species were collected between Waukegan and Zion, Illinois in 1972 (Commonwealth Edison Company 1972). Lake whitefish occupy deep water areas except during early spring when they move into shoals and spawn in shallow waters during the fall (Scott and Crossman 1973).

Longnose suckers have more recently been reported at Waukegan in 1976 and at the Great Lakes Naval Training Station in 1975 (Natural Land Institute 1981). This sucker lives in deep, cold, clear waters. In Ohio the species has been reported entering water less than 7.5 meters deep in the spring, presumably to spawn (Trautman 1957).

ARCHAEOLOGICAL AND HISTORIC RESOURCES

The lakebed at site 9 is not part of Waukegan Harbor; it may or may not have been disturbed by dredging and construction. If the site contains submerged archaeological properties (historic wrecks), their number, nature, and significance is unknown. The adjacent shoreline at site 9 is landfill. The area to be dredged has been disturbed by periodic dredging, last done in 1969; it does not contain any significant cultural material.

SOCIAL SETTING

The immediate area is generally vacant industrial space, with some railroad tracks and yards still in use. The immediate urban area is somewhat depressed. The major portion of waterborne commerce in Waukegan Harbor is shipping of building cement and gypsum received by Gold Bond Building Products and Huron Cement Company which are both divisions of National Gypsum Company. In 1982, 114,000 tons of building cement were received and in 1981, 130,000 tons of building cement and 81,000 tons of gypsum were received. A commercial fishing fleet of eight active boats also operates out of the harbor. Thirty-six tons of fresh fish were unloaded at the harbor in 1982 and twenty-five tons were unloaded in 1981. The Port of Waukegan is also homesite to a number of small and large scale industries, including OMC Johnson and Outboard Marine Corporation, together employing over 2,000 persons. Other industries include Falcon Marine and a marine contractor.

Another key use of the Port of Waukegan is recreational boating. Currently, the Waukegan Port District operates 158 slips and moorings as well as 103 dry dock spaces. Directly to the north of Slip 3, Larson Marine Service houses approximately 300 small pleasure craft for storage and repair. Since the mid 70's the Waukegan area has been recognized as one of the major co-ho and salmon fishing areas on Lake Michigan. The recreational use of the Waukegan Harbor has grown significantly over the past twenty years and has served as the stimulus for the construction of new harbor facilities to the south of Waukegan Harbor which were completed in 1985. The new facility includes 761 new slips for small pleasure craft. This expansion will also increase the number of charter fishing boats from 35 in 1983 to a projected 60 charter boats operating out of the Waukegan area in 1987.

SECTION 4

ENVIRONMENTAL CONSEQUENCES

GENERAL IMPACTS

Construction and operation of a CDF at site 9 would not have a significant adverse impact upon community cohesion or growth, tax revenues, public services or facilities, air quality, or noise levels; no people or farms would be displaced.

PHYSICAL AND GROUNDWATER IMPACTS

Negative impacts upon groundwater resources are not expected to result from implementation of the proposed plan.

AIR QUALITY IMPACTS

No significant violations of air quality standards are expected to occur as a result of the construction of the proposed CDF or the operation of the mechanical dredge during the dredging season.

SEDIMENT QUALITY IMPACTS

Up to 187,500 cubic yards of "heavily polluted" sediments will be dredged from the Federal channel and harbor areas and placed in the CDF. Another 75,000 cubic yards of clean, sandy sediments will be dredged and disposed of by other means. Such dredging will significantly improve the overall channel sediment quality as the underlying layers to be exposed by dredging are not contaminated. However, the northernmost portions of the harbor will not be dredged at the same time; these sediments contain high levels of contaminants including PCB's between 50 and over 500 ppm (classified as "toxic" by U.S. EPA), and the potential exists for movement of these more highly polluted sediments into the Federal channel by wave and boat action.

WATER QUALITY IMPACTS

Dredging the harbor will have several impacts to harbor water quality. The dredge itself will cause an increase in turbidity in nearby waters. Increased turbidity is considered short-term, unlikely to produce irreversible effects, and more of an aesthetic rather than biological problem (Hirsch et al., 1978, Stern and Stickle 1978). These resuspended sediments will have an increased potential for releasing PCB's and other contaminants from sediment particles into the water column, thus, increasing bioavailability of contaminants and releasing oxygen demanding constituents which lowers dissolved oxygen levels. These impacts are considered relatively short-term and will last only during the dredging season. Since dredging will ultimately remove heavily-polluted sediments from the aquatic environment the overall, long-term water quality will improve.

Construction and filling of the proposed CDF will also increase turbidity and contaminant release as discussed under dredging. These impacts are considered short-term. Water quality projections for the CDF filtrate is currently not available. This information will be included in future environmental reports. However, virtually all (99.999999%) suspended solids will be removed from escaping water by the sand filter in the dike wall. Therefore, the only contaminants that may enter Lake Michigan are those that are highly water soluable.

AQUATIC COMMUNITY IMPACTS

No Action Alternative

Under the no action alternative, aquatic populations in Waukegan Harbor will continue to be influenced by existing and future sediment accumulations. Tissue samples of fish (USEPA, 1981) have shown high accumulation of PCB's (averaging 18 ppm in Waukegan Harbor). Continued exposure by fish and other organisms moving into and out of contaminated and toxic (Slip #3, Superfund) sediments will likely increase the export of PCB's and other pollutants into the Lake Michigan food chain.

Contaminant pathways into Waukegan Harbor-Lake Michigan fishes could be through direct absorbtion from the water column, from contact with sediments either in place or resuspended, and through the food chain. The predominant pathway of contaminants to aquatic organisms is through direct partitioning (diffusion) of a contaminant to fish gill tissue (Rubinstein et al, 1984). This direct mode of contaminant concentration results from contact with sediments and from contaminants in the water column.

The diffusion (equilibrium partitioning) of sediment constituents between sediments, sediment interstitial waters and the water column provides a steady state (at equilibrium) release of sediment contaminants to the overlying water column. Contaminants can also be released to the water column during physical disruption and resuspension of bottom sediments. Contaminant release may influence water quality and make contaminants available to aquatic organisms. Studies have shown that fish may directly absorb contaminants from the water column and concentrate them in tissues (Holden, 1962; Kudo and Mortimer 1978, Roesijadi et al., 1978; Bjerk and Bverik, 1980; Rubinstein et al., 1984). Of the contaminant pathways to aquatic organisms, direct partitioning across the gills is generally considered dominant (Rubinstein et al., 1984).

Bioconcentration of contaminants by aquatic organisms in direct contact with the sediments has been reported by Halter and Johnson (1977), Kudo and Mortimerr (1978), McLeese et al., (1980), Peddicord (1980), Varanasi and Gmur (1981), Rubinstein et al., (1984), and Seelye and Mac (1984). Contaminant uptake by aquatic organisms living in or upon the sediments has also been reported to be much greater than by organisms in the water column (Halter and Johnson, 1977; Kudo and Mortimer, 1978).

Contaminated sediments resuspended in the water column have the same effect on organisms in the water colums as those in close association with bottom sediments. Resuspended sediments may be ingested or may collect on endangered birds and may possibly be used for spawning by the lake whitefish (though there is presently no data to support this). This loss of habitat would be permanent, but considered insignificant in comparison to the amount of similar habitat found throughout the Lake Michigan shoreline. The removal of PCB's and other contaminants from the aquatic environment by placing in a CDF would be considered a long-term benefit to all shoreline fish and wildlife, including endangered species, and would outweigh any short-term impacts.

The U.S. Fish and Wildlife Service and the Illinois Department of Conservation have been contacted concerning possible impacts to Federal and state threatened and endangered species. Their comments concerning threatened and endangered species will be incorporated in future planning reports.

ARCHAEOLOGICAL AND HISTORIC IMPACTS

Maintenance dredging will be done in areas already disturbed by periodic dredging; no archaeological or historic properties will be affected. The Illinois SHPO has been consulted, and is expected to concur with this determination.

The lakebed at site 9 is not part of Waukegan Harbor, and may and or may not have been disturbed by dredging or construction. It is not known whether site 9 contains any significant archaeological properties (such as historic shipwrecks). An underwater survey will be conducted at a later planning stage to determine whether such properties exist, and to assess impacts to them. The Illinois Historic Preservation Agency (SHPO) has been asked to comment on this matter.

SOCIAL IMPACTS

Dredging and CDF construction would cause temporary, localized increases in noise, odor, dust, and truck traffic levels during dredging and construction.

Construction of a CDF at site 9 would affect the future use and development of the adjacent lakefront. Local land use or master plans should be carefully considered in future planning.

If the harbor was not dredged the current level of ship traffic would be expected to continue. However, shoaling near the mouth of the Federal channel could restrict commercial traffic and allow only smaller ships or ships carrying less cargo to enter the harbor. This would increase shipping costs and possibly cause area industries to rely more on shipping by truck or rail. Several harbor industries rely heavily on shipping by water. Loss of this method of transportation could result in lost business opportunities, more unemployment, and further economic depression in the Waukegan area. If the harbor and channel are dredged and maintained, area industries would be assured of an effecient means of transporting their products and area employment could potentially increase.

SECTION 5

COORDINATION

The Illinois Department of Conservation (Endangered Species Protection Board), Illinois Historic Preservation Agency (SHPO), and U.S. Fish and Wildlife Service were consulted during the preparation of this preliminary assessment.

SECTION 6

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STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
GEOLOGICAL SURVEY DIVISION
URBANA, ILLINOIS

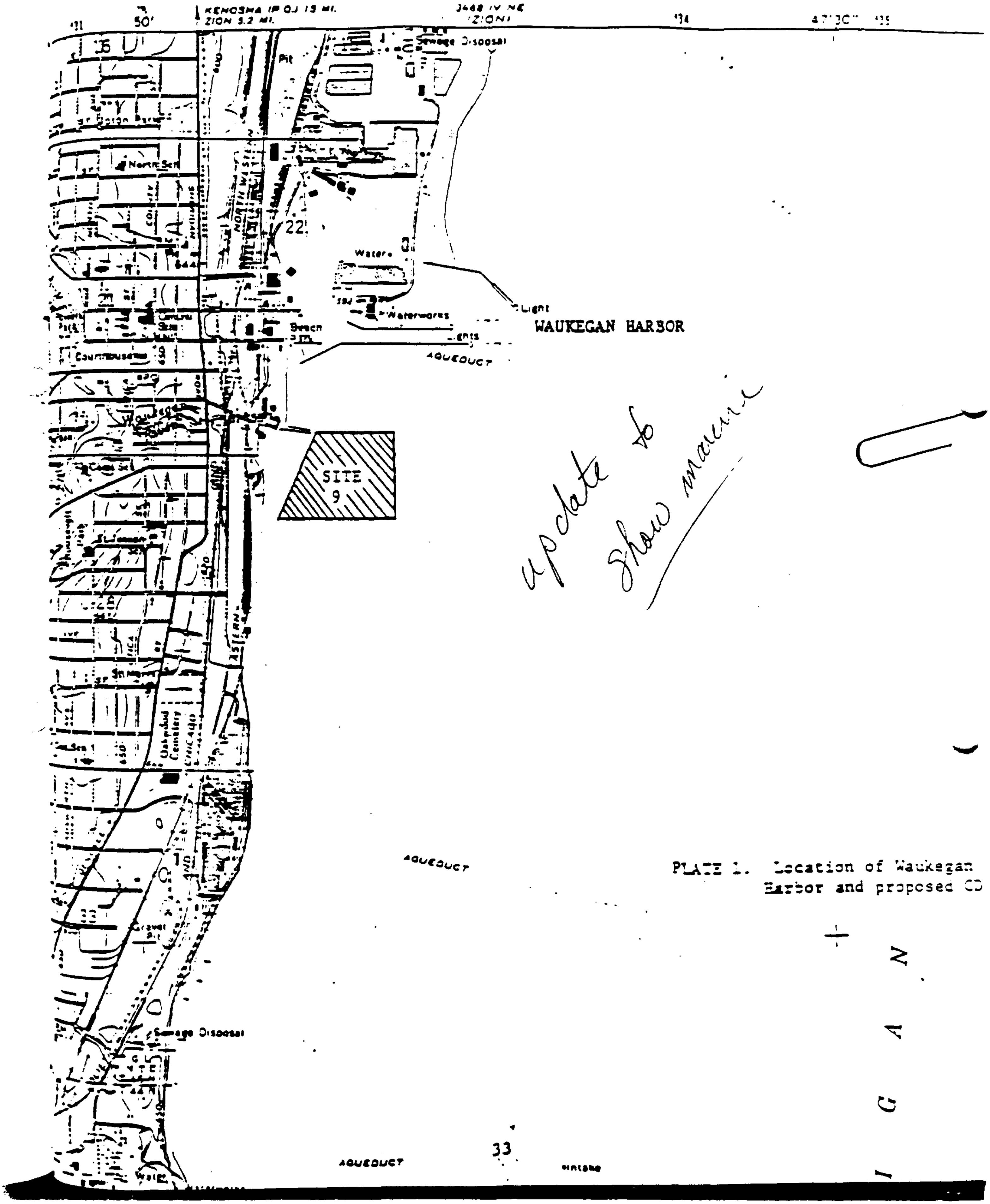
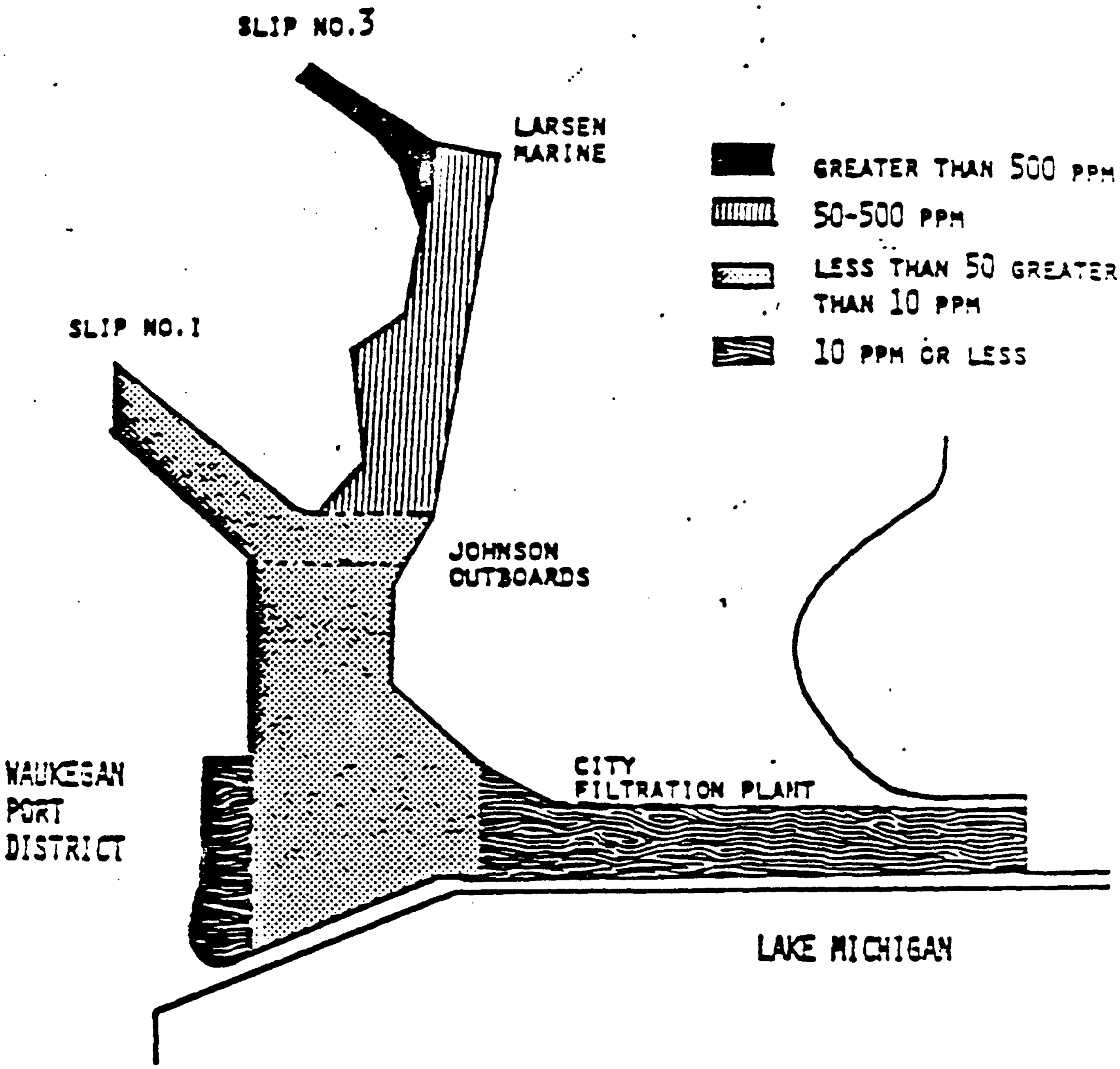


PLATE 1. Location of Waukegan
Harbor and proposed CD



SCALE: 1"=500' (APPROXIMATE)

PLATE 2. DISTRIBUTION OF PCB CONTAMINATION IN WAUKEGAN HARBOR SEDIMENT.

(from US EPA report "The PCB Contamination Problem in Waukegan, Illinois", January 1981)

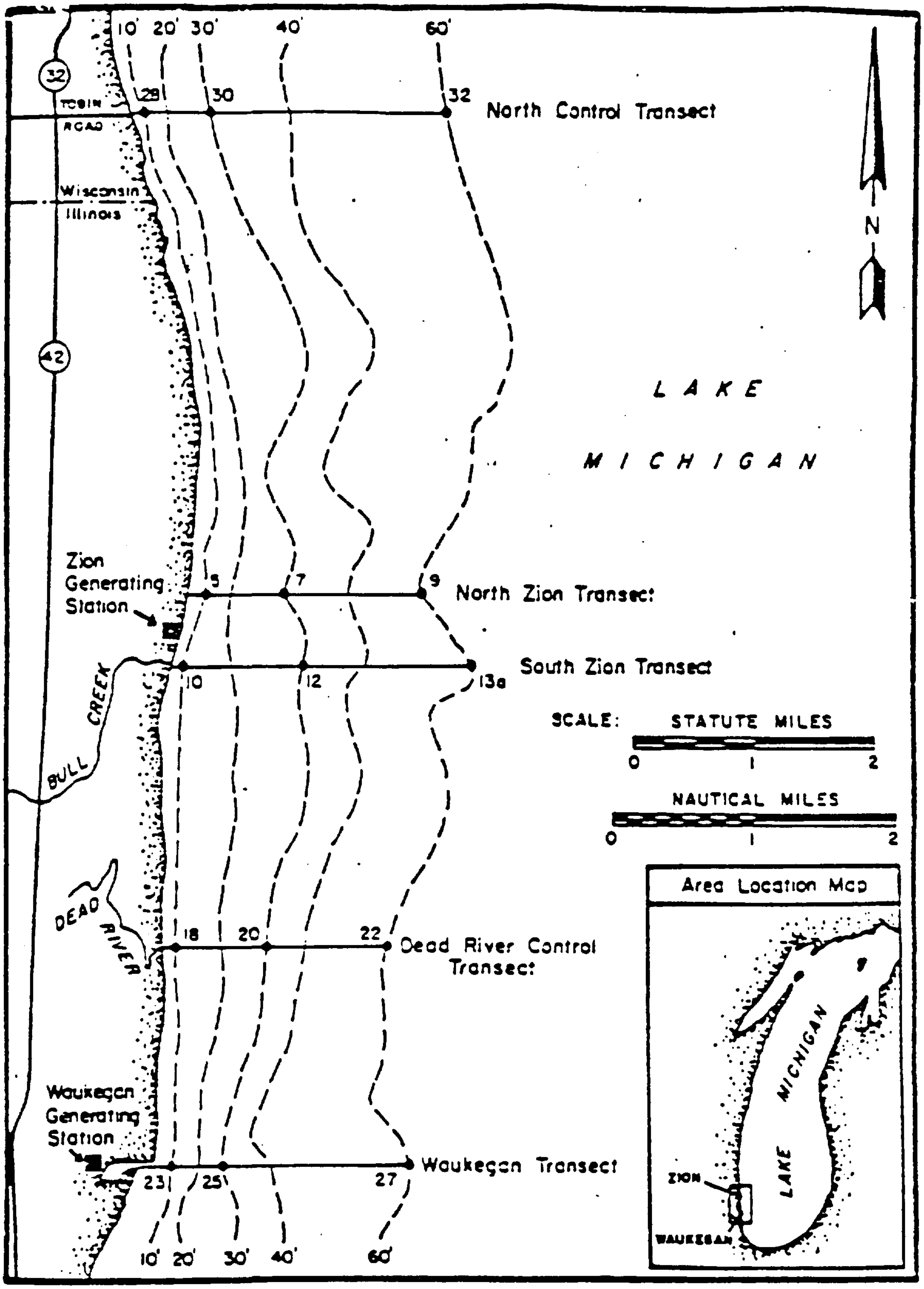
APPENDIX
TO
PRELIMINARY ENVIRONMENTAL ASSESSMENT OF SITE 9, WAUKEGAN HARBOR, ILLINOIS,
MAINTENANCE DREDGING AND CONFINED DISPOSAL FACILITY, MAY 1986

(EXCERPTS FROM MARCH 1975 CORPS FEIS FOR WAUKEGAN HARBOR, ILLINOIS)

Excerpts from:

Report to Commonwealth Edison Company, Chicago, Illinois.

Environmental Monitoring in Lake Michigan near Zion and Waukegan Generating Stations January 1972 through December 1972 Volume II.



Field sampling locations for phytoplankton, southwestern Lake Michigan near Zion and Waukegan, Illinois, January - December 1972.

List of phytoplankton taxa encountered in southwestern Lake Michigan near Zion and Waukegan, Illinois, 1972. I = 5% of phytoplankton by reporting units (u) and/or by biovolume (b). D = important in 30% of all samples.

BACILLARIOPHYTA (Diatoms)

Achnanthes Bory
- *clevei* Grunow
- *clevei* var. *rostrata* Hustedt
- *lanceolata* Breb.
- *lanceolata* var. *dubia* Grunow
- *lanceolata* var. *rostrata* Hustedt
- Iu *minutissima* Kutz.
- *peragalli* var. *parvula* (Patr.) Reim.
- unidentified sp.

Amphipleura pellucida Kutz.

Amphora Ehrenberg
- *coffeaeformis* Agardh
- *delicatissima* Krasske
- *ovalis* Kutz.
- *ovalis* var. *pediculus* Kutz.
- *perpusilla* Grunow
- unidentified sp.

Du, Ib *Asterionella formosa* Hassall

Attheva zachariasi J. Brun.

Caloneis Cleve
- *bacillum* (Grun.) Mereschkowsky
- unidentified sp.

Cocconeis Ehrenberg
- *diminuta* Pant.
- *disculus* Schum.
- *pediculus* Ehrenberg
- *placentula* Ehrenburg
- *placentula* var. *euglypta* (Ehr.) Cleve
- Ib *placentula* var. *lineata* (Ehr.) Cleve
- unidentified sp.

Coscinodiscus unidentified sp. Ehrenberg

Cyclotella Kutz.
- *antiqua* W. Smith
- *atomus* Hustedt
- *bodanica* Eulenst.
- *comta* (Ehr.) Kutz.
- Iu *glomerata* Bachmann
- *kutzingiana* Thwaites
- *kutzingiana* var. *planetophora* Fricke
- *meneghiniana* Kutz.
- *meneghiniana* var. *plana* Fricke
- *michiganiana* Skvortzow

Iu, Ib	ocellata Pant.
	pseudostelligera Hustedt
Iu	stelligera Cl. u. Grun.
Iu	unidentified sp.
	unidentified sp. 1
	Cymatopleura
Ib	solea (Breb.) W. Smith
	solea var. apiculata (W. Smith) Ralfs
	Cymbella Agardh
	microcephala Grunow
	prostrata (Berkeley) Cleve
	sinuata Gregory
	turgida (Gregory) Cleve
	ventricosa Kutz.
	unidentified sp.
	Diatoma DeCandolle
	elongatum var. minor Grunow
Iu, b	tenue Agardh
	tenue var. elongatum Lyngbye
	vulgare Bory
	unidentified sp.
	Diploneis Ehrenberg
	puella (Schumann) Cleve
	smithii (Breb.) Cleve
	unidentified sp.
	Epithemia unidentified sp. Brebisson
	Fragilaria Lyngbye
Iu	capucina Desmazieres
	capucina var. mesolepta (Rabh.) Grunow
	construens (Ehr.) Grunow
Du, b	crotonensis Kitton
Iu, b	intermedia Grunow
	leptostauron (Ehr.) Hustedt
Iu	pinnata Ehrenberg
	pinnata var. lancettula (Schumann) Hustedt
	vaucheriae (Kutz.) Peters
	unidentified sp.
	unidentified sp. 2
	Frustulia vulgaris Thwaites
	Gomphonema Agardh
	angustatum (Kutz.) Rabh.
	olivaceum (Lyngb.) Kutz.
	olivaceum var. minutissima Hustedt
	parvulum Kutz.
	unidentified sp.
	Gyrosigma Hassall

scalproides (Rabh.) Cleve
spencerii var. *nodifera* Grunow
unidentified sp.
Hantzschia amphioxys (Ehr.) Grunow
Melosira Agardh
ambigua (Grun.) O. Muller
distans (Ehr.) Kutz.
granulata (Ehr.) Ralfs
granulata var. *angustissima* Muller
Iu, b *islandica* O. Muller
Iu *italica* (Ehr.) Kutz.
Iu unidentified sp.
Meridion ciculare Agardh
Navicula Bory
anglica Ralfs
bacillum Ehrenberg
capitata Ehrenberg
capitata var. *hungarica* (Grun.) Ross
cari Ehrenberg
costulata Grunow
cryptocephala Kutz.
cryptocephala var. *veneta* (Kutz.) Grunow
decussis Ostr.
exigua (Greg.) O. Muller
gastrum (Ehr.) Kutz.
gracilis Ehrenberg
gregaria Donkin
hambergii Hustedt
hungarica Grunow
hungarica var. *linearis* Oestrup
longirostris Hustedt
menisculus Schum.
minima Grunow
placentula (Ehr.) Grunow
platystoma Ehrenberg
pupula Kutz.
pupula var. *rectangularis* (Greg.) Grunow
salinarum Grunow
salinarum var. *intermedia* (Grun.) Cleve
unidentified sp.
unidentified sp. 2
Neidium Pfitzer
dubium (Ehr.) Cleve
dubium fo. *constrictum* Hustedt
unidentified sp.

	Nitzschia Hassall
Iu	aciculari W. Smith
	amphibia Grunow
	angustata (W. Smith) Grunow
	apiculata (Greg.) Grunow
	dissipata (Kutz.) Grunow
	fonticola Grunow
	frustulum Kutz.
	holsatica Hustedt
	linearis W. Smith
	palea (Kutz.) W. Smith
Iu	paleacea Grunow
	sigma (Kutz.) W. Smith
	tryblionella Hantzsch
Iu, b	unidentified sp.
	unidentified sp. 2
	Opephora martyi Heribaud
	Pinnularia unidentified sp. Ehrenberg
Ib	Pleurosigma unidentified sp. W. Smith
Du, b	Rhizosolenia eriensis H. L. Smith
	Rhoicosphenia curvata (Kutz.) Grunow
	Rhopalodia unidentified sp. O. Muller
	Stauroneis unidentified sp. Ehrenberg
	Stephanodiscus Ehrenberg
Iu, b	alpinus Hustedt ex Huber-Pestalozzi
Iu, b	astraea (Ehr.) Grunow
	astraea var. minutula (Kutz.) Grunow
Du, Ib	binderanus (Kutz.) Krieger
	hantzschii Grunow
Du	hantzschii vel tenuis Grun.-Hust.-Skabitschewsky
	invisitatus Hohn and Hellerman
Iu	minutus Grunow ex Cleve and Moll.
Ib	niagarae Ehrenberg
	tenuis Hustedt
Ib	transilvanicus Pant.
Du, Ib	unidentified sp.
Du	unidentified sp. 2
	unidentified sp. 3 - astraea
	Surirella Turpin
	angusta Kutz.
	ovalis Brebisson
	ovata Kutz.
Ib	unidentified sp.
	Synedra Ehrenberg
	acus Kutz.
	delicatissima W. Smith
	delicatissima var. angustissima Grunow

Iu *filiformis* Grunow
parasitica W. Smith
radians Kutz.
rumpens Kutz.
ulna (Nitzsch) Ehrenberg
Ib *ulna* var. *chaseana* Thomas
ulna var. *danica* (Kutz.) Grunow
ulna var. *longissima* (W. Smith) Brun
ulna var. *subaecualis* Grunow
Iu unidentified sp.
Tabellaria
fenestrata var. *geniculata* Cleve
Du, b *flocculosa* (Roth) Kutz.
Tropidoneis unidentified sp. Cleve
Iu Unidentified centrics
Unidentified pennates

CHLOROPHYTA (Green Algae)
Ankistrodesmus
falcatus (Corda) Ralfs
falcatus var. *mirabilis* (West and West) G. S. West
fractus (West and West) Brunnthaler
spiralis (Turner) Lemmermann
Arthrodesmus unidentified sp. Ehrenberg
Characium hookeri (Reinsch) Hansgirg
Chlamydomonas unidentified sp. Ehrenberg
Chlorogonium elongatum Dangeard
Closteriopsis
longissima Lemmermann
longissima var. *tropica* West and West
Closterium unidentified sp. Nitzsch
Coelastrum
Ib *cambricum* Archer
Iu, b *microporum* Naegeli
Ib *reticulatum* (Dang.) Senn
Ib *sphaericum* Naegeli
Cosmarium Corda
depressum (Naegeli) Lundell
unidentified sp.
Crucigenia
apiculata (Lemm.) Schmidle
irregularis Wille
quadrata Morren
rectangularis (A. Braun) Gay
Dictyosphaerium pulchellum Wood

Elakatothrix

gelatinosa Wille

viridis (Snow) Printz

Franceia ovalis (France) Lemmermann

Geminella minor (Naeg.) Heering

Gloeoactinium limneticum G. M. Smith

Gloeocystis

Ib ampla (Kutz.) Lagerheim

planctonica (West and West) Lemmermann

Golenkinia radiata (Chod.) Wille

Gonium pectorale Muller

Kirchneriella

contorta (Schmidle) Bohlin

lunaris (Kirch.) Moebius

lunaris var. dianae Bohlin

Ib obesa (W. West) Schmidle

Lagerheimia

ciliata (Lag.) Chodat

citriformis (Snow) G. M. Smith

Micractinium pusillum Fresenius

Mougeotia (C. A. Agardh) Wittrock

Ib gracilima (Hass.) Wittrock

unidentified sp.

Nephrocytium

agardhianum Naegeli

limneticum G. M. Smith

Oocystis

Ib borgei Snow

crassa Wittrock in Wittrock and Nordstedt

Ib gloeocystiformis Borge

Db lacustris Chodat

parva West and West

Iu, b pusilla Hansgirg

solitaria Wittrock in Wittrock and Nordstedt

submarina Lagerheim

Pandorina morum (Mull.) Bory

Pediastrum

boryanum (Turp.) Meneghini

duplex Meyen

duplex var. clathratum (A. Braun) Lagerheim

duplex var. cohaerens Bohlin

duplex var. rotundatum Lucks

simplex (Meyen) Lemmermann

simplex var. duodenarium (Bailey) Rabenhorst

tetras (Ehr.) Ralfs

Platymonas unidentified sp. G. S. West

Plectonema notatum Schmidle

Polyblepharides unidentified sp. Dangeard

- Quadrigula
  - chodatii (Tan.-Ful.) G. M. Smith
  - closterioides (Bohlin) Printz
  - lacustris (Chod.) G. M. Smith
- Radiofilum irregulare (Wille) Brunnthaler
- Scenedesmus
  - abundans (Kirch.) Chodat
  - acuminatus (Lagerheim) Chodat
  - arcuatus Lemmermann
  - arcuatus var. platydisca G. M. Smith
  - armatus (Chodat) G. M. Smith
  - bijuga var. alternans (Reinsch) Hansgirg
  - bijuga var. flexuosus (Lemm.) Collins
  - brasiliensis Bohlin
  - carinatus (Lemm.) Chodat
  - denticulatus Lagerheim
  - dimorphus (Turp.) Kuetzing
  - intermedius Chodat
  - longispina Chodat
  - longus Meyen
  - longus var. naegelii (Breb.) G. M. Smith
  - obliquus (Turp.) Kuetzing
  - opoliensis P. Richter
  - quadricauda (Turp.) Brebisson
  - quadricauda var. maximus West and West
  - quadricauda var. westii G. M. Smith
- Schizochlamys
  - compacta Prescott
  - gelatinosa A. Braun in Kuetzing
- Schroederia
  - ancora G. M. Smith
  - setigera (Schroed.) Lemmermann
- Selenastrum gracile Reinsch
- Sphaerocystis schroeteri Chodat
- Spondylosium Brebisson
  - planum (Wolle) W. and G. S. West
  - unidentified sp.
- Staurastrum Meyen
  - curvatum W. West
  - unidentified sp.
- Stichococcus unidentified sp. Naegeli
- Stigeoclonium unidentified sp. Kuetzing
- Tetraedron Kuetzing
  - caudatum (Corda) Hansgirg
  - minimum (A. Braun) Hansgirg
  - muticum (A. Braun) Hansgirg

regulare Kuetzing
regulare var. incus Teiling
unidentified sp.
Tetraspora
Ib gelatinosa (Vauch.) Desvaux
lacustris Lemmermann
Ib lamellosa Prescott
Tetrastrum staurogeniaeforme (Schroed.) Lemmermann
Trochiscia reticularis (Reinsch) Hansgirg
Ulothrix unidentified sp. Kuetzing

CHRYSOPHYTA (Golden-Brown Algae)

Aulomonas sp. Lackey
Chrysosphaerella longispina Lauterborn
Cladomonas Stein
Iu, b fruticulosa Stein
unidentified sp.
Codonosiga unidentified sp. Senn
Diceras phaseolus Fott
Iu Dichotomococcus lunatus Fott
Dinobryon Ehrenberg
bavaricum Imhof
Iu cylindricum Imhof ex Ahlstrom
Iu, Db divergens Imhof
pediforme (Lemm.) Steinecke
Iu, b sociale Ehrenberg
unidentified sp. 1
Harpochytrium unidentified sp. Lagerheim
Mallomonas
acaroides Pertz
caudata Iwanoff
producta (Zacharias) Iwanoff
pseudocoronata Prescott
tonsurata Teiling
Iu Monosiga unidentified sp. S. Kent
Ophiocytium
capitatum Wolle
capitatum var. longispinum (Moebius) Lemmermann
Peroniella
hyalothecae Gobi
planctonica G. M. Smith
Rhizochrysis limnetica G. M. Smith
Stipitococcus West and West
apiculatus Prescott
urceolatus West and West
unidentified sp.
Iu, b Uroglenopsis americana (Calkins) Lemmermann

CYANOPHYTA (Blue-Green Algae)

	Anabaena Bory		
		circinalis Rabenhorst	
		flos-aquae (Lyngb.) Brebisson	
		unidentified sp.	
Ib	*Aphanizomenon flos-aquae* (L.) Ralfs		
	Aphanocapsa Naegeli		
		elachista W. and G. Smith	
		unidentified sp.	
	Aphanothece		
Ib		*castagnei* Brebisson	
		clathrata G. S. West *in* West and West	
Iu		*nidulans* P. Richter	
	Chroococcus		
		limneticus Lemmermann	
		pallidus Naegeli	
Iu		*prescottii* Drouet and Daily *in* Drouet	
		turgidus (Kuetzing) Naegeli	
	Coelasphaerium		
		kuetzingianum Naegeli	
Du		*naegelianum* Unger	
	Gloeocapsa aeruginosa (Carm.) Kuetzing		
	Gomphosphaeria		
Iu		*lacustris* Chodat	
Iu		*lacustris* var. *compacta* Lemmermann	
Iu, b	*Lyngbya* unidentified sp. Agardh		
	Merismopedia		
Iu		*convoluta* Brebisson *in* Kuetzing	
		glauca (Ehr.) Naegeli	
		punctata Meyen	
	Microcystis		
		aeruginosa Kuetzing *emend.* Elenkin	
		incerta Lemmermann	
	Oscillatoria Vaucher		
		amoena (Kuetz.) Gomont	
Iu, b		*geminata* Meneghini	
Ib		*limnetica* Lemmermann	
Iu, b		*tenuis* Agardh	
		unidentified sp.	
	Stichosiphon unidentified sp. Geitler		
Iu	Unidentified blue-green filaments		

EUGLENOPHYTA

	Euglena	
		polymorpha Dangeard
		proxima Dangeard

Lepocinclis
acuta Prescott in Prescott, Silva, and Wade
ovum (Ehr.) Lemmermann
Trachelomonas Ehrenberg
crebea (Kellicott) Deflandre
unidentified sp.

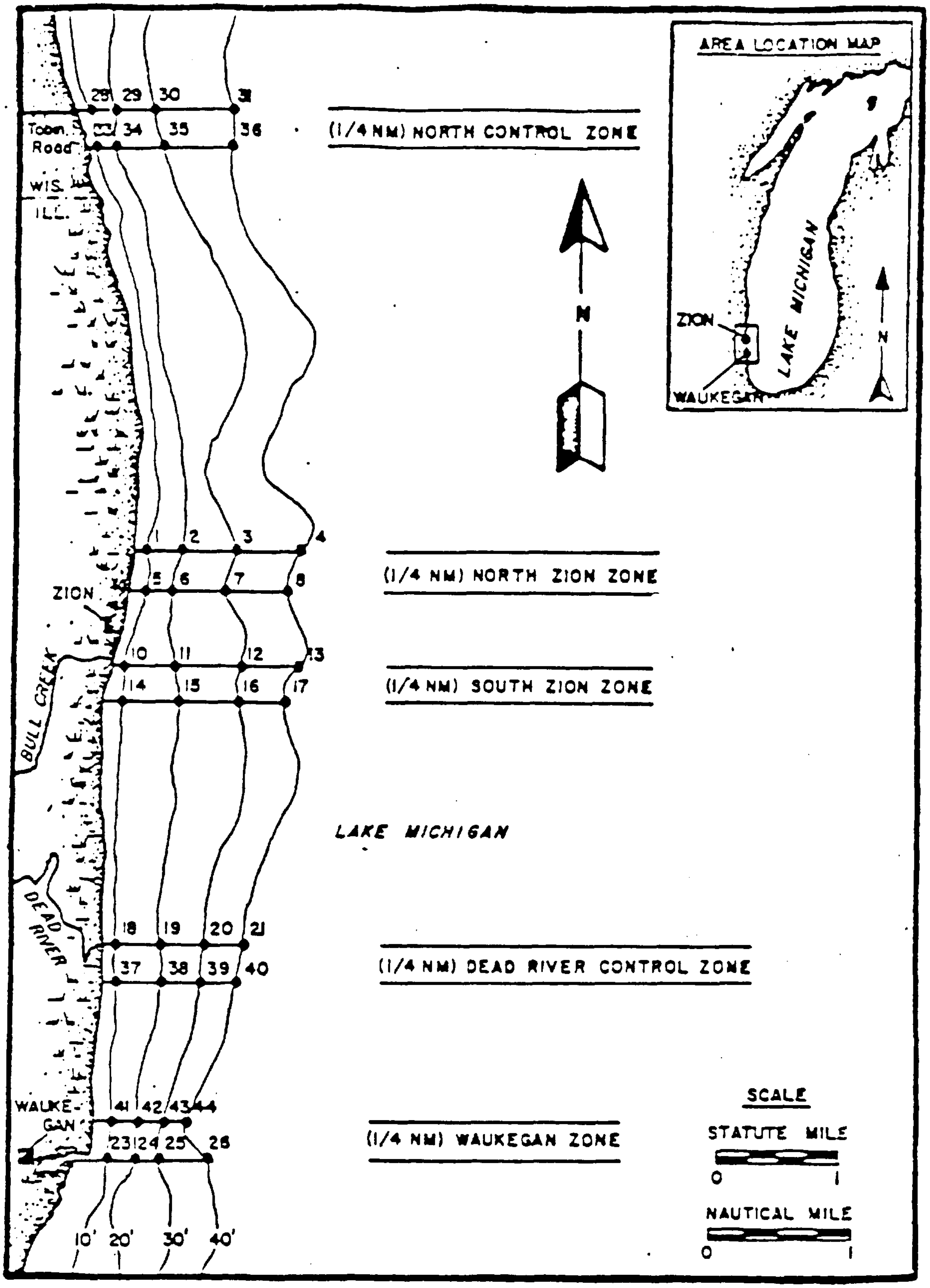
PYRRHOPHYTA
Ib Ceratium hirundinella (O. F. Muell.) Dujardin
Glenodinium unidentified sp. (Ehr.) Stein
Peridinium unidentified sp. Ehrenberg

MISCELLANEOUS
Rhodomonas unidentified sp. Karsten
Unidentified flagellate 1
Unidentified flagellate 2

List of zooplankton encountered in southwestern Lake Michigan near Zion and Waukegan, Illinois 1972.

Rotifera
Crustacea
Copepoda
nauplii
calanoid copepodites
cyclopoid copepodites
harpacticoid copepodites
Cyclops bicuspidatus thomasi S. A. Forbes
C. vernalis Fischer
Diaptomus spp. (female)
D. ashlandi (male) Marsh
D. minutus (male) Lilljeborg
D. oregonensis (male) Lilljeborg
D. sicilis (male) S. A. Forbes
Epischura lacustris S. A. Forbes
Eucyclops agilis (Koch)
Eurytemora affinis (Poppe)
Limnocalanus macrurus Sars
Mesocyclops edax (S. A. Forbes)
Orthocyclops modestus (Herrick)
Paracyclops fimbriatus poppei (Rehberg)
Tropocyclops prasinus (Fischer)
harpacticoida
Cladocera
Alona spp. Baird
A. quadrangularis (O. F. Muller)
Bosmina longirostris (O. F. Muller)
Ceriodaphnia spp. Dana
C. lacustris Birge
C. quadrangula (O. F. Muller)
Chydorus sphaericus (O. F. Muller)
Daphnia spp. O.F.M.
D. galeata mendotae Birge
D. longiremis Sars
D. parvula Fordyce
D. retrocurva Forbes
Diaphanosoma spp. Fischer
D. leuchtenbergianum Fischer
Eubosmina coregoni (Baird)
Eurycercus lamellatus (O. F. Muller)
Holopedium gibberum Zaddach
Leptodora kindtii (Focke)

Leydigia spp. Kurz
L. quadrangularis (Leydig)
Macrothrix spp. Baird
M. hirsuticornis Norman and Brady
M. laticornis (Jurine)
Polyphemus ped nne)
Amphipoda
Pontoporeia aff rom



Benthos sampling locations in southwestern Lake Michigan, near Zion and Waukegan, Illinois, January through December 1972.

List of benthic organisms encountered in southwestern Lake Michigan near Zion and Waukegan Illinois, 1972.

- Aschelminthes
  - Nematoda
- Cnidaria
  - Hydrazoa
    - Hydroida
      - Hydridae
        - Hydra
- Platyhelminthes
  - Turbellaria
    - Rhabdocoela
- Annelida
  - Oligochaeta
    - Plesiopora
      - Enchytraeidae
      - Naididae
        - Nais Muller
        - Piguetiella michiganensis Hiltunen
        - Stylaria lacustris (Linnaeus)
        - Uncinais uncinata (Orstedt)
        - Vejdovskyella intermedia (Bretscher)
      - Tubificidae
        - Unidentified immature tubificidae with capilliform chaetae
        - Unidentified immature tubificidae without capilliform chaetae
        - Aulodrilus americanus Brinkhurst & Cook
        - Aulodrilus pluriseta (Piguet)
        - Ilyodrilus templetoni (Southern)
        - Limnodrilus angustipenis Brinkhurst & Cook
        - Limnodrilus cervix Brinkhurst
        - Limnodrilus claparedianus Ratzel
        - Limnodrilus hoffmeisteri Claparede
        - Limnodrilus hoffmeisteri variant Claparede
        - Limnodrilus profundicola (Verril)
        - Limnodrilus spiralis Eisen
        - Limnodrilus udekemianus Claparede
        - Peloscolex freyi Brinkhurst
        - Peloscolex multisetosus longidentus Brinkhurst & Cook
        - Peloscolex multisetosus multisetosus (Smith)
        - Potomothrix moldaviensis Vejdovsky & Mrazek
        - Potomothrix vejdovskyi (Hrabe)

- *Tubifex ignotus* Stolc
- *Tubifex tubifex* Muller

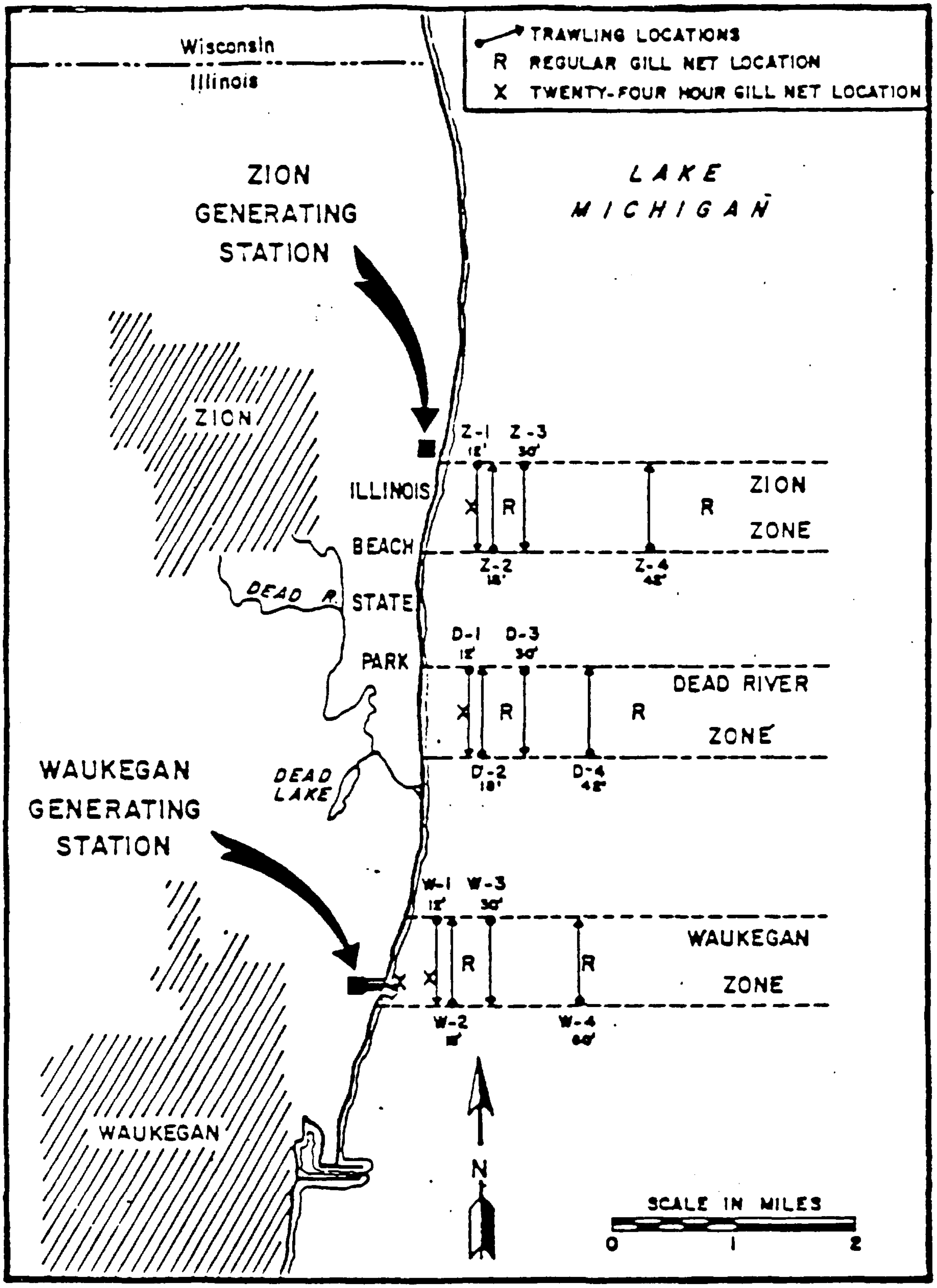
- Prosopora
  - Lumbriculidae
    - *Stylodrilus heringianus* Claparede

- Hirudinea
  - Rhynchobdellida
    - Glossiphoniidae
      - *Glossiphonia complanata* (Linnaeus)
      - *Helobdella stagnalis* (Linnaeus)
    - Piscicolidae
      - *Pisicola geometra* Linnaeus
  - Arhynchobdellida
    - Erpobdellidae
      - *Dina microstoma* Moore
      - *Dina parva* Moore

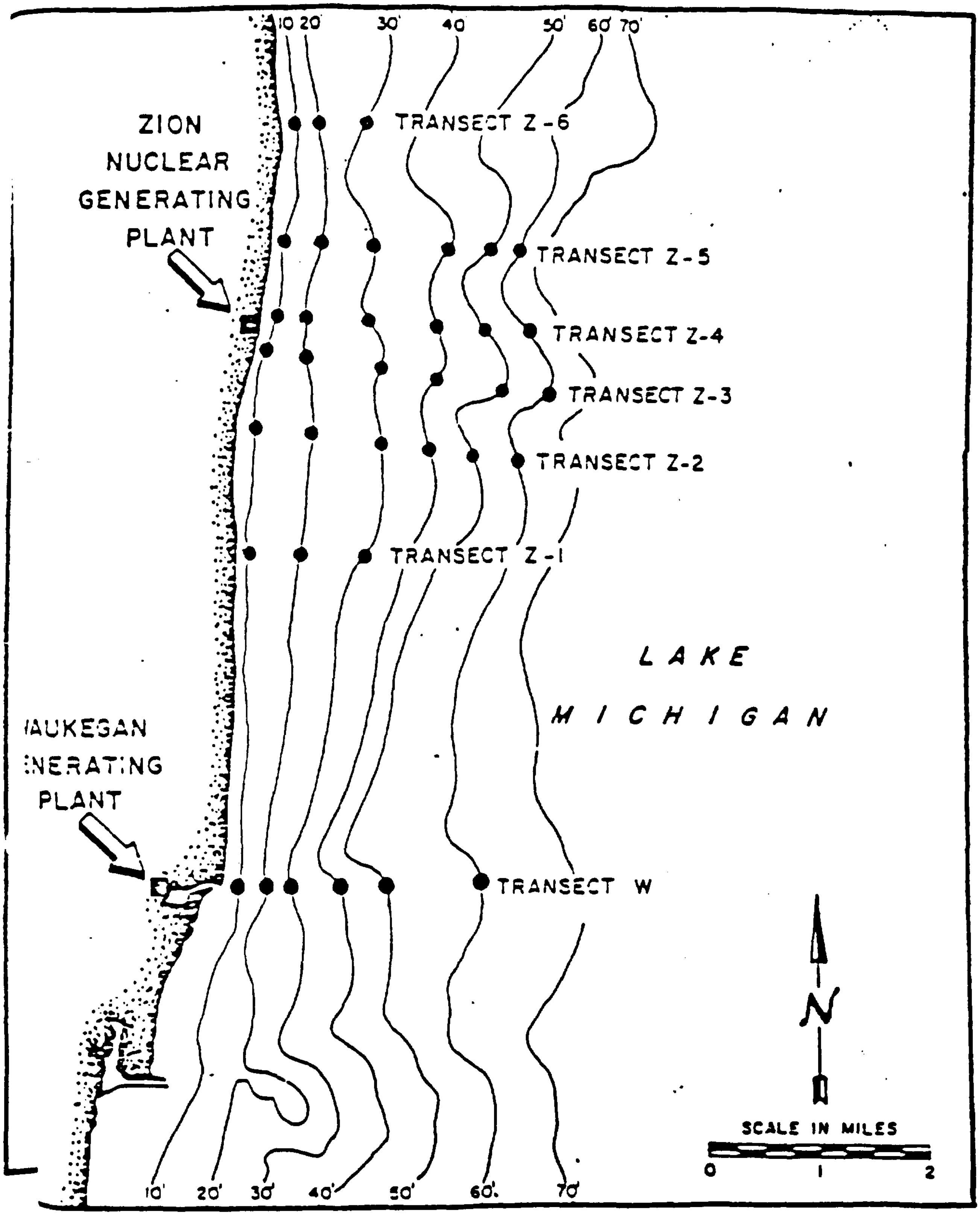
- Arthropoda
  - Crustacea
    - Ostracoda
    - Mysidacea
      - Mysidae
        - *Mysis relicta* Loven
    - Isopoda
      - Asellidae
        - *Asellus brevicaudus* Forbes
        - *Asellus intermedius* Forbes
    - Amphipoda
      - Talitridae
        - *Hyalella azteca* (Saussure)
      - Haustoriidae
        - *Pontoporeia affinis* Lindstrom
  - Arachnida
    - Acarina
      - Hydracarina
  - Insecta
    - Hemiptera
    - Trichoptera
      - Hydropsychidae
        - *Hydropsyche* Pictet
    - Coleoptera
      - Elmidae
        - *Dubiraphia* Sanderson

- Diptera
  - Chironomidae
    - *Chironomus attenuatus* Walker
    - *Cladotanytarsus* Kieffer
    - *Cryptochironomus* Kieffer
    - *Cryptocladopelma* Lenz
    - *Heterotrissocladius* Sparck
    - *Micropsectra* Kieffer
    - *Monodiamesa tuberculata* spec. nov. Saether
    - *Parachironomus* Lenz
    - *Paracladopelma* Harnisch
    - *Parakiefferiella* Thienemann
    - *Polypedilum* (Fallax group) Kieffer
    - *Potthastia* (Kieffer)
    - *Procladius bellus* Loew
    - *Tanytarsus* Van der Wulp
    - Thienemannimyia Group Fitkau

- Mollusca
  - Gastropoda
    - Ctenobranchiata
      - Amnicolidae
        - *Somatogyrus* Gill
      - Valvatidae
        - *Valvata perdepressa* Walker
        - *Valvata sincera* Say
        - *Valvata sincera nylanderi* Dall
        - *Valvata tricarinata simplex* Gould
    - Pulmonata
      - Physidae
        - *Physa* Draparnaud
      - Lymnaeidae
        - *Lymnaea auricularia* Linnaeus
  - Pelecypoda
    - Heterodonta
      - Sphaeriidae
        - *Pisidium amnicum* (Muller)
        - *Pisidium idahoense* Roper
        - *Pisidium lilleborgi* Clessin
        - *Sphaerium corneum* (Linnaeus)
        - *Sphaerium fabale* Prime
        - *Sphaerium nitidum* Clessin
        - *Sphaerium striatinum* (Lamarck)



Fish sampling locations in the Waukegan-Zion sampling area, 1972



Egg and larvae sampling locations, 1972.